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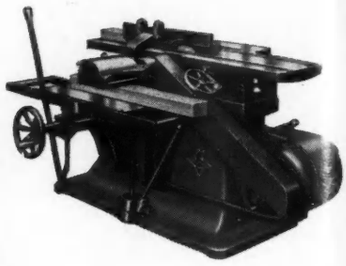

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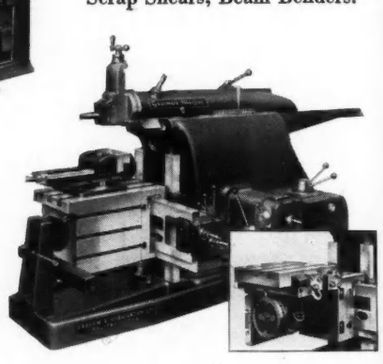

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RESEARCH ASSOCIATIONS

THE value and influence of the research associations is increasing steadily. Every year there is a rise in the number of firms making use of them. The fact that they are subsidised by the Government must encourage many firms, who might otherwise remain content with their own resources, to pay the relatively small annual subscription and thus give themselves at least the facilities used by their competitors. Some firms, it has been suggested, regard the research associations chiefly as trouble-shooters and information bureau for themselves; others consider them to be centres of research and development which save them expenditure on this kind of work. The annual income of the 41 research associations was £4 million in 1952, of which £1·3 million was in the form of Government grants. Many of the associations are still expanding and there is always the possibility that new associations will be established to serve industries which are not already provided for.

The report of the Manchester Joint Research Council which was reviewed on this page last week expressed concern that only three-quarters of all firms are in industries for which there exists a research association doing scientific work directly connected with their activities. In view of the unlimited range of industries in Britain, such a proportion could reasonably be regarded as high. Some of the firms constituting the neglected quarter have found that a research association whose work is only indirectly related to their own can render valuable assistance. The titles, and therefore the functions, of the associations are related in nearly every case to a particular end-product, such as motor vehicles, electrical equipment, instruments, coil springs, cotton and turbines, but there are two outstanding examples of associations which study engineering processes, namely, the British Welding Research Association and the Production Engineering Research Association. This type of association can serve a very wide range of firms.

The results of work carried out by the associations are issued in the form of bulletins and reports, or articles in the technical press, but industrial firms also profit by making personal visits to their associations or, occasionally, by visits from a representative of the association. The British Cast Iron Research Association, for example, sent an operational research team on 170 visits to the foundries of member firms during the year ended September 30, 1953. The British Non-Ferrous Metals Research Association was particularly active in its contacts with member firms, according to the latest annual report of the Department of Scientific and Industrial Research from which these figures are taken. In 1952, the liaison staff made 256 visits to members and, in the other direction, 1,200 visitors came to the laboratories, in addition to hundreds who came on the Association's open days. All the research associations are regularly assisting members in answering technical inquiries by letter and telephone.

It is impossible to assess the degree to which research association results are turned to good account in industry. The value of receiving an answer to a specific inquiry could usually be estimated, but no one could say what benefits flow from the thousands of visits which take place every year. The value of published work, also, is indeterminable: the bulletins, abstracts, and reports are circulated along many channels, and although they must have an immediate impact, varying according to the needs of a firm at the moment of receipt, they can also lie unused for several years before, with a fresh problem to be solved, they are taken down from the library shelves to be examined with a new sense of their significance.

It would be wrong to assume, however, that the best possible use is being made of the research associations. Medium-sized firms, in which the directors and senior staff are familiar with the day-to-day technical problems of the design and production departments, are probably well able to maintain profitable liaison on the basis of personal visits and correspondence. Small firms can similarly secure advantages even if they have only one member of their staff – not necessarily a highly-qualified man – who is alive to the possibilities. But in large firms, unless there is an exceptionally efficient system for ensuring the flow of technical information, it is unlikely that contact is made at every point where the research association has something to offer. The same consideration will, of course, apply in any firm which has not given adequate thought to the problem. How, for example, is the published literature to be circulated and examined? If a visit is to be paid to the research association, who should go on behalf of the firm? The general manager or chief engineer is probably equipped to examine the work of the laboratories with a broad understanding of his firm's needs, but a comparatively junior designer or production engineer may be able to serve them with greater success because his mind is concentrating on a limited number of problems and because he knows he has much to learn. The cross-fertilisation of ideas is in direct proportion to the number of contacts.

Weekly Survey

GLASS AS A LUBRICANT

In a notable paper read in London and reproduced in abridged form on page 463 of this issue, Mr. J. Sejournet, a French engineer, states that the successful hot extrusion of plain-carbon steels and austenitic-stainless, and other special steels is dependent on the use of the correct lubricant. He emphasises that to ensure the adequate lubrication of the steel in the extrusion press, the material used must be applied solid and become viscous, but not liquid, when in contact with the hot billet. Glass or glass-like materials seemed likely to meet the required conditions and these materials, in fact, are now in regular use at the Persan Works, near Paris, of the author's company, the Comptoir Industriel d'Etirage et de Profilage de Métaux. In an informative cinema film exhibited by Mr. Sejournet at the same meeting it was shown that the lubricant is used in the form of a cylindrical wad of glass wool apparently some 3 in. in length, termed a cartridge. This is placed against the die in the container of the extrusion machine, in front of the hot billet. When extruding pierced billets for the production of tubes, a glass-wool sheath is placed over the mandrel of the extrusion machine. The lubrication provided in this manner is continuous and the extruded product emerges from the die wrapped in a coating of glass of a thickness of 20 microns, or about 0·0001 in. With the object of removing the remains of this film of glass, the extruded product is dipped in a bath containing a dilute (2 per cent.) solution of hydrofluoric acid.

A problem connected with the hot extrusion of steel, which has not yet been completely solved, is that concerned with the formation of scale on the billets when heating them to the extrusion temperature, in the neighbourhood of 850 deg. C. A final heating in a bath of barium chloride is satisfactory but costly and, of the solutions to the problem now under consideration, that proposed for plain carbon steels is to heat them in a conventional gas or fuel-oil furnace and then rapidly remove the scale by means of high-pressure water sprays. For stainless and other special alloy steels, two of the methods now being studied involve the use of low-frequency electric furnaces or gas furnaces employing a controlled atmosphere.

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CROSS-CHANNEL ELECTRIC POWER SUPPLY

It is probably no exaggeration to say that the proposal to link Britain and France by a submarine power cable will, if it is successfully brought to fruition, open a new chapter in the supply of electricity and even in the history of the two countries. Such a means of connection is not entirely unknown, but most of the existing submarine power cables are short and are operating at voltages below about 60 kV. Moreover, the conditions in the Channel are hardly favourable to the scheme, steep cliffs being present on the British and a sandy foreshore on the French side, with water varying in depth up to 216 ft. and constantly moving to and fro with the tide. In addition, there is considerable shipping, with all the attendant risks from anchors, and a number of charted and uncharted wrecks to offer further hazards. Communication cables, too, occupy some of the route and would have to be crossed by a power cable.

Nevertheless, the conditions with regard to electricity supply in the two countries indicate that mutual assistance would be both possible and advantageous. In this country 99 per cent. of the electricity is produced in thermal stations, while in France rather over half is generated by water power. There is considerable diversity of demand, both periodical and day by day, so that it would be possible by interconnection to reduce the generating plant capacity in each country and to adopt methods of energy transfer which would lead to worth-while economies.

It was with these considerations in mind that a Joint Committee, representative of the British and French national electricity authorities, was appointed in 1950 to investigate the technical problems involved in manufacturing and laying the necessary cable. Two years later this body reported that there did not appear any insuperable difficulty to the installation of such a link and that the savings which could be effected would make it economically attractive. On the other hand, they felt, quite wisely, that as so little was known about the hazards associated with submarine power cables, a period of test and development should precede actual construction. Since then, exhaustive investigations have been made on both sides of the Channel, the results of which to date are described in a paper which was presented by Mr. D. P. Sayers, Mr. M. E. Laborde and Mr. F. J. Lane at a meeting of the Institution of Electrical Engineers on April 1.

The contents of this paper, a summary of which will be found on page 464 of this issue, indicate that there is little doubt that suitable cables for transmitting power across the Channel can be manufactured and installed. There are some uncertainties as to the risk of breakdown after installation and as to the practicability of effecting quick and satisfactory repairs. The trials that have taken place should, however, provide useful information on these subjects and perhaps lead to a more optimistic outlook. There is also some doubt as to whether an interconnecting cable of the size suggested would enable the two systems to operate continuously in parallel, but here again experience should provide an answer. If the trials prove the scheme to be practicable, and as economic as it appears to be, France and Britain will benefit from an early decision to start.

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APPOINTMENTS BUREAU

The year 1953 was one of great activity for the Professional Engineers' Appointments Bureau, over 7,600 names of engineers being submitted for vacancies. The registrar and secretary, Mr. J. Muil, A.M.I.E.E., reports that much work was done in placing young civil engineers who registered for either site or design experience, in order to help them obtain their associate membership of the Institution of Civil Engineers. There was a well-maintained demand for graduate civil engineers for design work, particularly with consulting engineers, and the requirements of many employers seeking senior staff were satisfied. Compared with the previous year, there was an increase in the number of overseas vacancies.

There was considerable activity in certain sections of mechanical engineering and it was possible to put forward well-qualified candidates for the vacancies notified. Engineers with production, design and development experience in the light industries were in constant demand, but fewer vacancies were available for the semi-commercial and administrative posts which seemed to be the first choice of many candidates registering. In many cases employers who contacted the Bureau specified the type of engineer in which they were interested rather than notified particular vacancies.

In electrical engineering, vacancies in the light-current field predominated and engineers with experience in electronics were relatively easy to place. Industry is looking for large numbers of experienced engineers in this field and is providing openings for young candidates for training. Though the Bureau conducted several hundred interviews with employers and electrical engineers of all ages, and by this personal service was able to satisfy many requirements, considerable benefit could have resulted from increased notifications by electrical employers of vacancies they have to offer.

The problem of placing the older engineer is still acute, except in the case of senior appointments requiring wide experience and the ability to undertake heavy responsibility. Many more engineers could have been placed by the Bureau if suitable living accommodation had also been offered. There appears to be increased reluctance on the part of young engineers to make their careers abroad. The possession of a university degree is, in many cases, the main factor in deciding whether an engineer is interviewed, often irrespective of experience.

The Bureau was set up in 1945 and financed by subscription from individual members. It is directed by a joint board composed of members nominated by the Institutions of Civil, Mechanical and Electrical Engineers but serving in their individual capacities. The aims of the Bureau are to assist members of the three institutions in finding posts, and to facilitate changes of appointments in appropriate circumstances. The address of the Bureau is 9 Victoria-street, London, S.W.1.

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THE ECONOMIC SURVEY

Two trends which developed in this country's economy during 1953 are of particular interest to engineers. The first of these was the recovery in consumer expenditure in the second part of the year which had a most favourable direct effect on the light engineering industry. The second was the failure of the engineering industry as a whole to increase its plant and equipment, although it probably just about maintained the volume of output achieved in 1952. These two phenomena are the more significant because they have carried on into the first quarter of this year and must, therefore, materially affect the capacity of the engineering industry to increase its exports and lower its costs this year, both of which are emphasised in the Economic Survey for 1954 as the most important aims to be achieved this year.

According to the Survey, consumer expenditure went up from £10·4 thousand million to £11 thousand million between the end of 1952 and the close of 1953. Allowing for changes in prices, the public spent £337 million more last year than in the year before. There were signs in the first half of last year that the motor-vehicle industry and those companies making household durable goods would have difficulty maintaining their sales in the second half of the year, but in the event companies in these industries had an outstandingly successful year. Other engineering industries which recorded a high level of sales were aircraft and companies making armaments and munitions. These industries also substantially increased their exports, against the general slightly downward trend of engineering exports in general, and aircraft exports were significantly higher in value than exports of ships.

Last year was a poor one so far as capital investment in the engineering industry was

concerned. The housing programme continued to absorb the greater part of the increase in the country's capital assets, whereas gross fixed investment by manufacturing industry remained unchanged over the year at £545 million. Electricity, gas and water went up from £242 million to £270 million and transport and communications from £227 million to £275 million. The last two categories may have added very slightly to their capital assets when allowance is made for increased prices, but the first group obviously reduced their assets. This was the investment background of the engineering industry immediately before the Budget and it makes a striking contrast with the objectives for 1954 which have been set for industry by the Survey.

The Economic Survey remarks that " during 1954 there will be resources available in the capital goods industries to provide both for an expansion of exports and for a higher rate of industrial investment. Increases in both directions are needed to provide a firm basis for the further development of the economy in future years." The aim of economic policy in 1954 is, in fact, the continued build-up of the sterling area's gold and dollar reserves against the day when either a more serious American recession than the present one may prove to be, or a worsening of the terms of trade, makes an impact on the British balance of payments. This policy can be achieved only if exports increase. The essential issue which comes out of the Economic Survey for 1954 thus becomes apparent. Official economic policy last year did not provide sufficient incentives to industry to invest in new plant and equipment on a large enough scale and so reduce costs; nor were markets, especially overseas ones, buoyant enough to encourage industry to embark on long-term plans for expansion. Higher productivity in a year when wage costs are certain to be increased can come only by further investment in plant and equipment. The engineering industry has, therefore, a large stake in any swing-over of the nation's resources from expenditure on consumer goods and housing to a more rapid re-equipment of industry.

LOCOMOTIVES OF THE FRENCH RAILWAYS

Intensive Utilisation

Although the number of steam locomotives in use on the French National Railways at the end of 1953 had declined by about 50 per cent. as compared with 1938, and the total of all locomotives and railcars in service – steam, electric and Diesel – was less by 43·6 per cent. than that for 1938, the traffic during the same interval increased by 35·8 per cent. This increase has been met by the more intensive utilisation of motive power, especially electric locomotives, and by a considerable expansion in the aggregate passenger-kilometres and metric-ton kilometres.

It is stated in *L'Année Ferroviaire*, 1954, compiled by the Société Nationale des Chemins de Fer Français and published by la Librairie Plon, 8 Rue Garancière, Paris 6e, that the mileage of electric locomotives is being increased yearly. Thus, in August, 1952, locomotive C-C 7101 covered 46,800 km., which is equivalent to travelling at a speed of 63 km. per hour and running 24 hours continuously day and night without interruption throughout the month. This, it is pointed out, is by no means a record; many other locomotives are capable of similar performances. For example, two DL locomotives of series 5500, delivered in 1942, covered 50,464 km. and 49,171 km. in July, 1953. The considerable increase in the loads conveyed is indicated by the fact that the sum of passenger-km. and *tonnes*-km., termed unités-kilomètriques, rose from 2·9 millions in 1938, to 7·1 millions in 1952.

The excellent results obtained with the C-C type express electric locomotives led to the placing of a large order for these engines. At the end of 1953, out of the 58 locomotives ordered, 37 had been delivered and were in service on the south-east and south-west regions. On the latter, the engines are used mainly on the Paris-Toulouse run, which includes, between Montauban and Limoges, many gradients of 10 mm. in 1 m. (1 in 100) and short-radius curves. An adhesion weight of 107 metric tons allows the new locomotives to haul the heaviest trains unassisted. In June, 1953, delivery commenced of the first of a new series of 35 mixed-traffic locomotives, type BB 8100, for the south-east and south-west regions on which they are employed hauling stopping passenger and fast goods trains. Trials of prototypes of direct-current locomotives BB 9001 and 9002, built by the Winterthur-Brown Boveri group, and BB 9003 built by the M.T.E. Oerlikon group, have commenced on the Paris-Lyons line. These engines weigh 80 *tonnes*. The suspension system and the connection between the bogies and the body are novel; other new features include the wide spacing of the axles of each bogie. Prolonged tests are necessary but trials to date have demonstrated that their stability at high speeds is excellent and that their traction characteristics are practically equivalent to the 107-*tonne* C-C 7100 class locomotives.

50-CYCLE CURRENT

For the Valenciennes-Thionville line, single-phase 50-cycle alternating current at 25 kV has been chosen and 105 locomotives have been ordered, 85 of the C-C type for iron-ore trains and 20 of the B-B type for mixed-traffic passenger and goods trains. The C-C locomotives will haul trains of 1,800 *tonnes* on gradients of 10 mm. per m., and of 2,400 *tonnes* on gradients of 6 mm. per m. The B-B locomotives will haul goods trains of 750 *tonnes* at speeds of 53 km. per hour on gradients of 10 mm. per m. and 900-*tonnes* passenger trains at 105 km. per hour on level sections of the track.

In 1953, the first of a series of 78 600-h.p. Diesel-electric locomotives were placed in service on branch lines. For hauling heavy goods trains on the non-electrified Grande Ceinture line, north of Paris, twenty 2,000-h.p. Diesel-electric locomotives will be placed in service this year. These engines have two three-axle bogies and weigh 120 *tonnes*.

* * *

Dial Cottage, where George Stephenson lived from 1805 to 1823, is on the left of this picture. An article on page 419 of last week's issue drew attention to the possibility of the cottage being demolished unless an interested person or organisation assumes responsibility for it.

Letters to the Editor

POWER OVER NATURE

SIR, May I be allowed to express my appreciation of your leading article of March 26, in which you discuss the theme of my play *The Burning Glass*, now at the Apollo Theatre, and of the preface to the published text. The problem raised is that of the whole position of scientific power in the modern world and is, therefore, as you rightly say, predominantly moral or spiritual. My scientist's burning glass (which, I am told by great experts on the ionosphere, is by no means impossible) is only a more refined and accurate substitute for the H-bomb, and I will say no more of it here. The play, which anyone is entitled to regard simply as an exciting story, must speak for itself.

It is an honour to a dramatist that his work should be discussed in ENGINEERING at all, and the honour, if I may say so, is the pleasanter to me because long ago your journal was my most awe-inspiring and least comprehensible nursery-book. Some of your readers will remember my father, who was President of the Institution of Civil Engineers. Out of veneration for him I struggled with your wisdom week after week. Indeed, I learned to read from ENGINEERING and the Bible. My father would have smiled to discover my name, which is his own precisely, on your leading page.

Your obedient servant,
CHARLES MORGAN.

March 30, 1954.

TRANSATLANTIC TELEPHONE

DETAILS OF NEW SUBMARINE CABLE AND REPEATER SYSTEMS

An agreement was signed in November last between the General Post Office, the American Telephone and Telegraph Company, the Canadian Overseas Telecommunication Corporation and the Eastern Telephone and Telegraph Company of Canada for the manufacture and laying of a submarine telephone cable system across the Atlantic. The British contribution to this important scheme will be the production of the major part of the cable and of the submerged repeaters between Newfoundland and Nova Scotia. The cables will also be laid by the British cable ship Monarch. The remainder of the cable and the submerged repeaters for the main crossing will be produced in the United States.

CABLE DESIGN

An initial order for the manufacture of nearly 90 per cent. of the first of the two telephone cables has been placed with Submarine Cables, Limited, Greenwich, London, S.E.10, a firm which is jointly owned by Siemens Brothers and Company, Limited, and the Telegraph Construction and Maintenance Company, Limited. It will be of the single coaxial type with an inner copper conductor made up of a wire 0·131 in. in diameter, surrounded by three tapes 0·0145 in. thick. Over this core there will be extruded a layer of polythene with a diameter of 0·62 in. which will be mixed with 5 per cent. of polyisobutylene or butyl rubber and a small amount of anti-oxidant to prevent any slight deterioration of its qualities during processing. Polythene is a synthetic thermoplastic hydrocarbon with a dielectric constant of 2·3, a power factor of 0·0003 and very high resistivity. It has already been used on more than 12,000 nautical miles of submarine cable as well as on land communication cables and on high-frequency cables for radar installations.

Surrounding the insulator will be an outer conductor consisting of a layer of six copper tapes. These tapes will be applied with a long lay and will be held in position by a copper binder tape and a protective tape, which will be applied with a short lay. On the deep-sea portion an armouring of twenty-four 0·086-in. diameter steel wires will be used, each wire being protected by a coating of compound and an impregnated fabric tape. The overall diameter of this part of the cable will be 1·2 in. and the weight 62 cwt. per nautical mile in air and 36 cwt. per nautical mile in water. Heavier armour will be used where the water is shallow and possibly double armouring on the shore ends and where a rocky bottom may be encountered.

MANUFACTURING ACCURACY

The manufacture of such a cable will naturally necessitate extreme accuracy, as is shown by the following considerations. The attenuation of 1,950 nautical miles of cable is about 900 decibels at the lower end and 3,200 decibels at the higher end of the transmitted frequency band. The transmission level at any frequency must be maintained so as to avoid overloading the repeaters at high levels or running into interference at low levels. Consequently, the variation of the attenuation with the frequency must be accurately equalised at each repeater. Moreover, predictions must be made of the pressure and temperature conditions at the sea bed, as the cable characteristics depend upon both these variables. A third consideration is that the deep-sea repeaters do not include matching units, so their gain will be affected by irregularities in the cable impedance due to reflection.

The project has, of course, only been made possible by the development of submerged repeaters. For the main crossing from Scotland to Newfoundland these repeaters will be of the type developed by the Bell Telephone Laboratories and installed in the Key West-Havana cables in 1950.* They are designed for installation under the cable armour, in which they form a bulge about 3 in. in diameter tapering off in a length of about 20 ft. to the cable diameter. This bulge is sufficiently flexible to pass through the gear of a cable ship so that laying and recovery in a depth of 2,500 fathoms will be facilitated. The repeaters, each of which will contain three valves, will be spaced at intervals of 37 nautical miles. Only one-way transmission will be provided on this part of the system, each cable transmitting a band of from 12 to 156 kilocycles.

"LUMP" REPEATERS

"Lump"-type repeaters developed by British engineers, 19 of which have already been laid in European coastal waters, will be used on the stretch of 310 nautical miles between Newfoundland and Nova Scotia.† Owing to the greater space available on this portion of the cable, filters permitting two-way working can be accommodated. One cable transmitting two frequency bands and providing separately for the speech channels in the two directions will therefore be sufficient. The repeater spacing will be less than on the main crossing, owing to the greater attenuation at the higher operating frequency. The technical problems in connection with this part of the work include the design of repeaters which will operate without attention over long periods under a hydrostatic pressure of 3 tons per square inch. The direct current necessary for their operation will be supplied from both ends of the cable through the inner conductor, a positive voltage of 2,000 volts being applied at one end and a negative voltage of 2,000 volts at the other on the long crossing. Finally, methods of locating faults and effecting repairs have had to be worked out.

36 SPEECH CHANNELS

These Atlantic cables will be 10 times longer than any other submarine telephone cables and will be the first to be laid at depths exceeding 1,000 fathoms. With carrier-frequency operation, a band of 144 kilocycles will be occupied by 36 speech channels. This will make 29 telephone circuits available between London and New York, and thus to the telephone systems of the two countries. There will be a further six circuits between London and Montreal, as well as a number of telegraph circuits to Canada. The new cables will provide a service which will be private and unexposed to the atmospheric interference which at present persists for 40 per cent. of the time. They will also enable better communication to be maintained with Australia and New Zealand via Vancouver.

* See J. J. Gilbert, *Bell System Technical Journal*, vol. 50, page 65 (1951).

† See R. J. Halsey, *Journal of the Institution of Electrical Engineers*, vol. 91, Part III, page 218 (1944).

STAYTHORPE TESTING STATION

TRIALS INAUGURATED ON TYPICAL 275-KV CABLES

Although it may be some time before 275-kV cables are required commercially, arrangements were recently made between the British Electricity Authority and the Cable Makers' Association to provide facilities for the manufacture and testing of sample lengths. A station which was formally inaugurated on Thursday, March 25, has therefore been set up near the Staythorpe power station where three cable manufacturers have each laid 100-yard test loops of single-core 275-kV cable, as well as straight joints and sealing ends. These lengths are to undergo intensive field trials at a normal voltage of 275 kV, but they will also be required to work continuously at 300 kV and to pass an impulse test of 1,050 kV.

The three test lengths are connected in series with one phase of the 275-kV line from Staythorpe to West Melton, isolating switches being provided so that any cable can be switched in or out of circuit. During the tests the surges to which the cables are subjected will be measured by a surge recorder, thus enabling permanent records to be made. Measurements of sheath temperature will also be taken to ascertain the maximum temperature of the conductors during load cycles, while records will be kept of the voltage and load on the overhead line.

IMPREGNATED PRESSURE AND OIL-FILLED CABLES

British Insulated Callender's Cables, Limited, 21 Bloomsbury-street, London, W.C.1, have installed two lengths of cable – a 275-kV impregnated pressure cable and a 275-kV oil-filled cable. The impregnated cable is designed to operate at a maximum stress at the conductor of 110 kV per centimetre, under a nitrogen pressure of 200 lb. per square inch. As the overhead line to which it is connected is only lightly loaded, a special arrangement has been adopted so that the conductor will attain a temperature of 80 deg. C., the maximum designed temperature for such cables operating under full-load conditions.

The conductor consists of a stranded centre of sixty-one 0·083-in. aluminium wires, covered with a paper separator, over which is stranded a single layer of forty-seven 0·066-in. aluminium wires. These wires will carry the current, giving an effective conductor area of 0·16 sq. in. The conductor is screened with metallised paper tapes over which the paper insulation is applied. The lead-alloy sheath is reinforced with tin-bronze strips which have been applied both longitudinally and circumferentially, and there is an anti-corrosive protection of polyvinyl chloride, rubber and hessian. The final overall diameter of the cable is 3·87 in.

The same firm's oil-filled cable has also been designed to operate at a maximum stress at the conductor of 110 kV per centimetre. It consists of a 16-mm. oil duct round which the conductor is formed. This comprises 111 0·074-in. tin-bronze wires giving a conductor area of 0·46 sq. in. As with the impregnated pressure cable, special arrangements were necessary to ensure the conductor attaining a temperature of 80 deg. C. Tin-bronze wires were therefore used to give an increased resistance and consequent temperature rise.

The conductor is screened with metallised paper tapes over which a metallic screen and a

copper-woven fabric tape are applied. The lead sheath is 0·115 in. thick, giving the cable a diameter of 3·43 in. The reinforcement comprises tin-bronze strips and an anti-corrosive protection of polyvinyl chloride, rubber and hessian is applied overall. The final overall diameter of the cable is 3·64 in.

JOINT DESIGN

The installation includes an impregnated pressure straight joint of a new type. The electrical design follows similar practice to that used for lower voltage impregnated pressure cables, but the cast plumbs have been replaced by a mechanical sealing arrangement and the inner lead sleeve has been omitted. The conductors are joined by a soldered flush-fitting ferrule, the overall diameter of which is equal to the diameter of the conductor. The impregnated pressure cable sealing ends consist of a condenser cone which is housed in anti-fog porcelains that are capable of withstanding the internal pressure of 200 lb. per square inch. The arrangement of the condenser cone permits the use of a relatively small diameter of porcelain. The straight joint and sealing ends for the oil-filled cable were specially designed for this installation, the sealing ends using the same type of porcelains as for the impregnated pressure cable sealing ends.

COMPRESSION CABLE

Enfield Cables Limited, Brimsdown, Middlesex, have submitted a cable which is the outcome of the experience gained with their 220-kV self-contained compression cables at the Fontenay Testing Centre of the Electricité de France, and with an experimental cable which has been tested for many years in their high-voltage laboratory. It has an oval conductor of 0·4 sq. in., which is screened with carbon paper and is designed to withstand a maximum stress of 150 kV per centimetre under a nominal gas pressure of 250 lb. per square inch. The dielectric thickness is 0·8 in., while the nominal loading is 200 MVA and the actual loading 120 MVA. With an overall diameter of 3·7 in., the cable weighs 16 lb. per single-core foot and a sample of it has withstood the firm's standard impulse test of 1,050 kV peak. Since installation, the cable has been successfully subjected to a direct-current test voltage of 550 kV for 15 minutes.

The construction of the cable and joint follows the usual design for self-contained compression cables and the cable is terminated in double-shed anti-fog pressure porcelain sealing ends. To comply with the electrical tests at the site, prefabricated condenser cones, manufactured by Standard Telephones and Cables, Limited, London, W.C.2, have been used to terminate the cable inside the porcelains. The normal compensator unit, gas-filling valves and gas-pressure gauges are provided.

The cable submitted by Pirelli-General Cable Works, Limited, Eastleigh, is a 275-kV cable of the oil-filled type. To match the overhead line, a prototype cable having a conductor size of 0·4 sq. in. was required but, since the transformers at present available will not fully load a cable of this size, a conductor of 70-30 brass wire has been used. This has enabled a cable to be designed with the necessary electrical and mechanical characteristics to meet the trial installation conditions with negligible change in conductor and insulation from the standard 0 4 sq. in. cable.

The conductor is screened and lapped with paper tapes, giving a dielectric of graded construction which is externally screened with metallised paper and single lead sheathed. The lead-alloy sheath is reinforced with bronze tapes and protected overall with an anti-corrosive serving. The final overall diameter is 3·18 in. The straight joint and two sealing ends, which form part of the Pirelli-General installation, have been designed in the light of experience gained with the 301-kV cables made recently for the Aluminum Company of Canada, Limited.

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PERSONAL

REAR-ADMIRAL E. G. A. CLIFFORD, C.B., C.B.E., has been promoted vice-admiral, as from April 1, in the room of ADMIRAL SIR PHILIP K. ENRIGHT, K.B.E., C.B., who reverts to the retired list on completion of his appointment as admiral superintendent, H.M. Dockyard, Devonport. Vice-Admiral Clifford becomes a Lord Commissioner of the Admiralty and deputy Chief of Naval Staff this mohth.

SIR CHARLES COLSTON, C.B.E., M.C., D.C.M., retired on April 3 from his position of chairman and managing director of Hoover Ltd., after 35 years with the company.

DR. H. L. SAUNDERS, F.R.I.C., who has been head of the Ironmaking Division of the British Iron and Steel Research Association since its establishment is to retire on April 30 on account of ill-health.

The Minister of Supply has appointed MAJOR-GENERAL G. N. TUCK, C.B., O.B.E., A.M.I.Mech.E., as deputy Controller of Munitions at the Ministry of Supply in succession to MAJOR GENERAL G. P. WALSH, C.B., C.B.E., D.S.O., with effect from May 17. General Walsh has been appointed assistant Controller of Munitions, a post he will continue to hold in a civilian capacity following his retirement from military service in the near future.

MR. G. M. WRIGHT, C.B.E., B.Eng., M.I.E.E., having reached the normal retiring age is relinquishing, as from April 1, his position as engineer-in-chief of Marconi's Wireless Telegraph Co. Ltd., Chelmsford, Essex, but will remain with the company as full-time general technical consultant. MR. B. N. MACLARTY, O.B.E., M.I.E.E., takes over the position of engineer-in-chief. His deputy will be MR. R. J. KEMP, the present chief of research. DR. E. EASTWOOD, M.Sc., M.I.E.E., deputy chief of research, succeeds Mr. Kemp as chief of the research establishment at Great Baddow, Chelmsford, Essex.

MR. BARRIE HEATH has been elected to the board of the Cambrian Wagon and Engineering Co. Ltd., Maindy, Cardiff. He is also managing director of Powell Duffryn Carbon Products Ltd.

As from May 1, MR. J. O. HITCHCOCK, B.Sc., will relinquish his position as assistant managing director of Henry Wiggin & Co. Ltd., Wiggin-street, Birmingham, 16, to assume the position of assistant to the chairman of the Mond Nickel Co. Ltd. He remains a member of the Wiggin Co. Board. MR. H. W. G. HIGNETT, B.Sc., superintendent of the Mond Nickel Co. development and research laboratory, has been appointed to the Wiggin Co. board and will take charge of technical (metallurgical) control and development in all the Wiggin Co.'s plants. His successor as superintendent of the laboratory is MR. H. EVANS. MR. R. E. ANSELL, M.Sc., A.R.I.C., manager of the sales department, now becomes a member of the Wiggin Co. board. MR. O. LEWIS JONES will become general production manager of all the Wiggin Co.'s plants and is to be succeeded as works manager at Birmingham by MR. C. E. WINFIELD. MR. A. B. GRAHAM will relinquish the position of general manager of the Wiggin Co.'s Zenith Works, Glasgow, on July 1, but will continue to undertake special duties in connection with production. The new works manager of the Zenith Works is to be MR. R. J. P. MACDONALD.

MR. H. P. WHITE, B.Sc., has been appointed head of the data and publications section of the technical service department of Mullard Ltd., Century House, Shaftesbury-avenue, London, W.C.2. The former head, MR. HARLEY CARTER, will now devote his entire time to the firm's educational service.

MR. MAURICE TATTERSFIELD has been appointed deputy general manager of the Loughborough Works of the Brush Electrical Engineering Co. Ltd.

MR. MONTAGUE BURNINGHAM relinquished his office of joint managing director of Keith Blackman Ltd., Mill Mead-road, Tottenham, London, N.17, on March 31. He retains his directorship and remains chairman. MR. D. S. WOODLEY, M.I.Mech.E., M.I.H.V.E., has undertaken the full duties of managing director as from April 1.

MR. S. P. MAYNARD, B.Sc. (Eng.) (Lond.), A.M.I.E.E., has been elected a director and appointed chief engineer of the Igranic Electric Co. Ltd., Bedford.

MR. L. M. BALLAM, hitherto senior representative at the London office of the Skefko Ball Bearing Co. Ltd., Luton, has been appointed manager at Bristol in succession to MR. E. Y. CASWELL, who, as announced on page 357, *ante*, has been transferred to the company's head office as sales manager.

MR. H. G. DAVIS, B.Sc., has been promoted to the position of assistant technical manager of Acheson Colloids Ltd., 18 Pall Mall, London, S.W.1. MR. G. J. BENNINGTON DAVIES, B.Sc., has been made assistant sales manager of the firm.

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BUSINESS CHANGES

THE DISTILLERS CO. LTD., Bush House, Aldwych, London, W.C.2, announce that, as from April 1, the CARBON DIOXIDE CO. LTD., ceased to trade as a separate company, and the whole of its business was transferred to a new division of its parent company, the Distillers Co. Ltd. The business is now conducted in the name of the CARBON DIOXIDE CO.—A DIVISION OF THE DISTILLERS CO. LTD.

ARDENTE ACOUSTIC LABORATORIES LTD., 62 Hornlane, Acton, London, W.3, announce that pressure on their manufacturing space has necessitated the moving of production elsewhere. Accordingly, a sole and exclusive licence to manufacture and sell their range of Intercom, Loud Hailers, marine Talk-Back systems and marine and general public address equipment has been granted to Easco Electrical Ltd., 6-8 Brighton-terrace, Brixton, London, S.W.9. (Telephone: BRIxton 4961-2-3.)

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OBITUARY

We regret to report the deaths of the following :

MR. ROBERT ALEXANDER NEILL, on March 29, in his 79th year. A late director of James Neill & Co. (Sheffield) Ltd., Napier-street, Sheffield, 11, he joined the company at the age of 18 and after 58 years of service, resigned his directorship in 1952 owing to ill-health.

MR. HENRY JOSEPH CHAYTOR, A.M.I.E.E., at the age of 74. For a number of years he was district engineer at the Liverpool Contracts office of the British Insulated Callender's Construction Co., Ltd., and at his retirement in June, 1940, was district engineer at Manchester, having served 47 years with the company.

MR. ALAN KIRK, A.M.I.E.E., on April 1 at the age of 83. He was formerly engineer to the Northcliffe Newpapers Group, Ltd., Carmelite House, London, E.C.4.

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THE ASSOCIATION OF CONSULTING ENGINEERS

The fortieth annual dinner of the Association of Consulting Engineers was held at the Dorchester Hotel, Park-lane, London, W.1, on April 1, with Sir Bruce White, K.B.E., chairman of the Association, presiding.

After the loyal toast the Rt. Hon. D. Heathcoat-Amory, P.C., M.P., Minister of State, Board of Trade, proposed the toast of the Association. He said that the policy of the Government was to work for an expansion in world trade and that this country could not afford rigid controls in view of its own position in world trade. In his reply, the chairman pointed out that many countries preferred the handling of tenders along with design and construction; he felt, therefore, that the linking of the work of the consultant with that of the contractor, in such circumstances, was in the best interests of those countries and of this country's share in world trade. Referring to his recent visit to the International Bank, Washington, D.C., he said the Bank was doing excellent work and only benefit could result from keeping in closer touch.

Mr. J. A. Banks, O.B.E., M.I.C.E., proposed the toast of the guests, and His Excellency Sir Claude Corea, K.B.E., the High Commissioner for Ceylon in the United Kingdom, replied.

ACCIDENT PREVENTION

Ironfounding, Steel and Rubber Manufacture

A three-day conference on the promotion of safety measures in industry, organised by the recently-formed safety committee of the Council of Ironfoundry Associations, 14 Pall Mall, London, S.W.1, took place at Ashorne Hill, Leamington Spa, early in March. In addition to ironfounding, a study was made of safety practices employed in the manufacture of steel and rubber.

The conference was opened with a paper on the Iron and Steel Foundries Regulations, 1953, and their relationship to safety, by Sir George Barnett, H.M. chief inspector of factories. Referring to accident prevention in foundries, Sir George stated that, while the total number of industrial accidents in this country was progressively decreasing, the tendency in foundries, during the past three years, had been for the total to rise.

In 1950 there were 24 fatal and 10,740 non-fatal accidents, and in 1951 there were 22 fatal and 11,033 non-fatal accidents; but in 1952 the totals had risen to 31 fatal and 11,232 non-fatal accidents. It was natural to expect that the percentage of accidents due to molten metal and other hot or corrosive substances should be considerably higher in foundries than in other sections of industry, but it was not really to be expected that the rate of eye accidents in foundries should be considerably higher than in industry generally, and that was certainly a type of accident to which special attention should be directed.

Although there was no scope for complacency in the founding industry, Sir George considered that the setting up of an accident-prevention committee and the organisation of the conference should do much to engender a greater awareness in the industry in respect to the need for precautions. An accident-prevention organisation should be established in all foundries as an essential and integral part of their works organisation.

In a paper on accident prevention in the iron and steel industry, Mr. J. Wadsworth, director of the Park Gate Iron and Steel Company, Limited, suggested specimen safety rules for adoption by foundries. He pointed out that an investigation by the British Iron and Steel Research Association had shown that a high proportion of workpeople left their firms within the first year of their employment, and that the accident-frequency rate among such persons was some 50 per cent. higher than among those who remained in their employment for several years.

LOST TIME

The author recommended that, where operatives could not be safeguarded by other means, there should always be available an adequate supply of personal safety appliances which were comfortable and acceptable to the employees concerned. He pointed out that some 29 per cent. of lost-time accidents in the iron and steel industry were due to the handling of objects of various kinds, and that many injuries of this type could be avoided, or reduced in severity, by the use of individual safety appliances.

Dr. H. T. Angus, M.Sc., development manager, British Cast Iron Research Association, reported on the work of the Association in connection with foundry hazards. He said that safety was equally applicable to long-term hazards as to short-term risks and that both were being dealt with by the Association's foundry atmospheres team. Increasing attention was being given in the industry as a whole to the cumulative effect of breathing dust-laden air. In this matter, emphasis had been laid upon siliceous dusts, which had been known for well over 25 years to be deadly in their cumulative effects. It was as a direct result of that knowledge that flint and sand blasting had disappeared completely from the founding and enamelling industries, and had been replaced by the use of crushed chilled-iron shot.

In general, the advantages of suppressing dust were likely to be even greater than the improvement of health and comfort, in that they included the reduction of wear and tear on foundry equipment and ancillary machinery. Considerable attention was being given to establishing the most satisfactory conditions for the control of dust at the knock-out, the one place in foundries where the creation of dust appeared to be inevitable.

HEATING AND VENTILATING

Dr. Angus stated that he had made no attempt in his paper to differentiate between harmful and so-called non-harmful dust. All dust was either unpleasant, or potentially harmful, and therefore must be eliminated or controlled.

Although, under the conditions existing in most British foundries, normal hazards from carbon monoxide were extremely small, demands for improved heating conditions might, by restricting ventilation, increase potential risks appreciably and, consequently, the design of combined foundry heating and ventilating systems had to be examined with much care, especially if the system in use involved the recirculation of the air. In the main, however, demands for the improvement of foundry atmospheres in this country had been due to pollution by sulphur dioxide.

In the paper on accident-prevention work in the rubber industry, by Mr. R. W. Lunn, of the Leyland and Birmingham Rubber Company, Limited, and throughout the conference, considerable emphasis was placed on the need for securing vigorous leadership for all safety schemes.

The printed report of the conference is expected to be ready shortly.

A COMPETITOR'S CATALOGUE

PARTS FOR JIGS AND FIXTURES

On April 2, Mr. Justice Lloyd-Jacob gave judgment in the case of *Purefoy Engineering Co., Ltd.* v. *Sykes Boxall & Co., Ltd.*, in which it was alleged that the defendants had infringed the plaintiffs' registered trade mark, had passed off their own goods as being the plaintiffs', and had infringed the plaintiffs' copyright in catalogue matter. His Lordship held that the claim for trade mark infringement was good, but that the plaintiffs had failed to establish either passing off or infringement of copyright.

The history of the matter was as follows. Mr. J. B. Purefoy had founded the plaintiff company in order to market his system of standardised parts for making up jigs and fixtures, the parts being re-usable as needed.* In order that this system should be successfully launched, the co-operation of industry was required, and Mr. Purefoy did a large amount of spade work in introducing it, although the idea of standard parts was not entirely novel, as similar parts were being made by another concern.

Between 1944 and 1948 Mr. S. M. Boxall (now of the defendant company) was employed by the plaintiffs as works foreman, and Mr. E. W. Sykes (now also of the company) was similarly employed and was responsible for the organisation of sales. Some time after they had left that employment (during which both must have acquired a detailed knowledge of the standard parts manufactured by the plaintiffs), they went into partnership in direct competition with the plaintiffs, later forming the defendant company.

As regards the allegation of passing off, the plaintiff company had instituted a system of code numbers by which the parts were known. The defendants, who offered some thirty parts, had a similar code, using letters and numerals. The evidence showed that several firms had adopted and used the plaintiff's reference numbers when asking for quotations for standard jig and fixture parts from the defendants. The object of using these reference numbers was as an easy means of identification, for there was no doubt that the plaintiffs' parts were well known. There was no evidence that the use of these numbers was intended to do anything more than identify parts and their size; there was no question of asking for parts of the plaintiffs' manufacture. Requests were phrased, "Similar to Purefoy No. ....," and the defendants' response did not disclose any intention to deceive. Where another's catalogue numbers were used in this way it was not right to infer a reference to the origin of the parts. Had a request stated, "We are given to understand that you manufacture Purefoy No. .... parts," and had the defendants, in response, supplied parts of their own manufacture, there might have been a passing off.

In respect of the copyright claim, a superficial examination of the plaintiffs' and defendants' catalogues disclosed a clear resemblance, and there were few differences. Both these points were relevant to the question of infringement. Where a competitor's catalogue is used as a pattern, or as a guide for making parts, the copyright is infringed, but if there is interest in a common subject-matter, as there was here, and the seller is not invoking the use of the other catalogue, there will be no infringement. It was submitted by the defence that these standard parts were well known in industry, and that they were copied as to style but not as to dimensions, which were arrived at by recollection and not from the catalogue. Although a study of both catalogues raised a *prima facie* presumption of infringement, there was no inherent improbability in the defence put forward. All that the defendants had done was to use the plaintiffs' catalogue as a model.

* The system was described in ENGINEERING, vol. 172, page 267 (1951).

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ELECTRICITY SUPPLY IN FEBRUARY

A Substantial Increase

During February, 1954, 6,016 million kWh were sold by the British Electricity Authority to the Area Boards, an increase of 13·6 per cent. over the output in the same month of last year. When corrected for the weather and the number of working days, however, the increase was 9·4 per cent., the weather having been considerably colder than a year earlier, although the number of working days was the same. The amount of electricity sent out by the Area Boards during the month was also 6,016 million kWh. Supplies to the "mainly industrial" areas increased by 13·1 per cent. and to the "mainly non-industrial" areas by 13·9 per cent.

INVESTMENT CASTINGS

Machining Reduced

The scope of investment castings was well indicated at an exhibition held recently in London by Deritend Precision Castings, Limited (a subsidiary company of the Deritend Stamping Company, Limited), Bays Meadow Works, Vines-lane, Droitwich, Worcestershire. The process was shown to be extremely versatile in that intricate shapes of small and medium sizes ranging in weight from a fraction of an ounce to several pounds can be produced in mild and medium-carbon steels and also in high-melting-point alloys, wear- and heat-resisting steels and similar materials, including nickel-chromium-molybdenum high-tensile steel, high-chromium tool steel, austenitic and martensitic stainless steels, case-hardening steels, silicon-manganese spring steel, carbon die steel, medium-carbon alloy steel and the cobalt-chromium alloy, Stellite.

Dimensional tolerances are given as $\pm 0{\cdot}005$ in. per inch; hence machining is confined to a minimum and normally only a little grinding is required. A fine, smooth finish gives the castings an attractive appearance which is valuable when subsequent polishing is necessary. When produced in an alloy which is normally machineable, however, the castings are as easy to machine as are rolled bars of the material. The castings, moreover, are homogeneous in structure and there is complete freedom from directional properties.

Investment castings have found application in aircraft equipment, textile machinery, pneumatic and machine tools, scientific and other instruments, etc.

A brief recapitulation of the method of producing investment castings may not be without interest. In the first place an accurate master pattern is prepared in brass, mild steel or Duralumin. This is an oversize model on which the necessary contraction allowance, requiring careful calculation, has been made. From this is produced a metal permanent die for making the wax models in the quantity required, by injection. After inspection, the wax models are mounted on suitable wax risers and feed bars, and the assembly is carefully precoated, this operation enhancing the smooth surface finish of the castings. The assembly is placed in a container, the mould material is poured in as a slurry and the container vibrated to ensure complete consolidation of the wet ceramic round the wax assembly. The mould is now dried and the temperature gradually increased until the wax is melted out. The mould is finally fired at a high temperature, during which process any residual wax is burnt out. Metal melted in a high-frequency induction furnace is poured into the mould and after cooling and solidification the mould is broken up, the components cut from the assembly and any adhering ceramic removed by shot-blasting.

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OUTPUT OF IRON CASTINGS IN 1953

According to statistics issued by the Council of Ironfoundry Associations, Crusader House, 14 Pall Mall, London, S.W.1, the total output of iron castings during 1953 was 3,638,000 tons, made up of 3,504,000 tons of grey and high-duty iron and 134,000 tons of malleable iron. The total is 3·2 per cent. lower than the corresponding total for 1952, which was an all-time record. A decline occurred in the production of iron castings for the engineering industries, but the output of ingot moulds, pipes and castings for buildings and domestic purposes continued to expand. At the end of 1953, 141,220 persons were employed in the industry.

Book Reviews

AN ENGINEERING TECHNIQUE APPLIED TO ECONOMICS

The Mechanism of Economic Systems. An Approach to the Problem of Economic Stabilisation from the Point of View of Control-System Engineering. By PROFESSOR ARNOLD TUSTIN. *William Heinemann, Limited, 99 Great Russell-street, London, W.C.*1. (25*s.* net.)

Professor Tustin, Head of the Department of Electrical Engineering at the University of Birmingham, holds this year the first Webster Professorship at the Massachusetts Institute of Technology. To inaugurate this well-merited distinction he delivered, on February 11 last, in Morss Hall of Walker Memorial, at Cambridge, Massachusetts, a public lecture on "Electrical Engineering in a New Kind of University." This choice of subject was completely appropriate both to the occasion and to the speaker. Professor Tustin, like the late Edwin S. Webster who endowed the chair of electrical engineering at M.I.T., has a special concern for the social and economic consequences of new scientific knowledge and ideas. He believes that the education of engineers must be designed for their full development as mature human beings, and that M.I.T., with its unique status in education, may become the prototype of a new kind of "university for the modern man," built around the teaching of applied science as its core.

Of the many and varied implications of this broad concept of a change from traditional classics to modern science as a basis for cultural education, two at least are outstanding. One is, that the aim and purpose of all knowledge, including science and its applications, should be the betterment of human welfare. The other, complementary to the first, is that specific problems of human welfare in fields such as medicine, nutrition or economics, as well as in the more obvious territories of man's control over natural resources to increase his comfort and convenience, are challenges to technologists in many different disciplines and inspiring subjects for purposeful future research. Lest it be thought that such views, however superficially laudable, are basically materialist, it is well to emphasise that Professor Tustin does not accept the too commonly drawn distinction between the domains of science and spirit. He regards as essential tasks for a technological university, first, to recognise that intellect is at best a tool which should be subordinated to good motives; then to clarify what is meant by "good"; and always to sustain an ever-rising standard of ethical values.

Against this background of the philosophy of a remarkable electrical engineer, Professor Tustin's recently published book on the mechanism of economic systems can be viewed more sympathetically than might seem possible, to engineers if not perhaps to economists, at a first consideration of the subject and its necessarily somewhat severe method of treatment. For most engineers nowadays are hard enough put to it to keep abreast of their own technology without attempting to master the intricacies of another which, while admitting its importance, they may well feel is founded on such uncertain and uncontrollable factors as to be inevitably remote from their precise ways of thinking and working. They may be gratified, none the less, that the theory and practice that have proved so successful in the realisation of engineering control systems, now appear to offer a new means of attack upon problems that economists have been able to propound but, hitherto, unable to solve.

It has been recognised for many years that close analogies exist between economic problems of the complex interactions among quantities such as income, capital, savings and investment, and automatic control systems in engineering where the corresponding interactions are among physical quantities affecting, say, the navigation of an aeroplane or the processing of chemicals. Many notable economists, J. M. Keynes among them, have found it useful to state such schemes of interdependence in the form of diagrams plainly similar to those used in control engineering theory. Closer examination of the nature of the interdependence between the related quantities serves to strengthen the analogy between the economic and the physical or engineering system, and hence to suggest that the methods of control analysis and the principles used successfully to achieve stability by means of engineering apparatus will prove at the least enlightening, and at best equally successful, in the economic sphere.

To explore this suggestion, to examine its varied aspects, to appreciate its difficulties and limitations, and to give practical expression to its possibilities, are tasks which Professor Tustin, who is an acknowledged authority on control theory, has undertaken with conspicuous success. Starting with a review of some of the simpler economic cause and effect systems, he shows what features predispose them to be inherently unstable, leading to cycles of booms and slumps; and how and where, in principle, stabilising measures may be introduced. Consideration of the irregular disturbances to which economic regimes are subject, and of the factors, additional to those studied in the elementary systems, which must be taken into account before qualitative explanations can become quantitative solutions (or qualitative ideas about stabilisation become deliberate, quantitative regulation) entails economic diagrams, or models, of increasing complexity. Professor Tustin's grasp of the way in which a great number of factors interact to influence a vast industrial economy excites an admiration that is surpassed only by the sense of competence with which he analyses the behaviour of such a system and indicates how it can be kept under control.

Many of the factors which influence economic stability – international politics, weather and harvests, technical development and invention, to mention a few of the most obvious – are clearly so indeterminate that the utmost the economist can hope, or be expected, to do about them is to estimate their differing future effects on the basis of intelligent assumptions. Similarly, and with only slightly less uncertainty, he has to make hypotheses regarding the time lags between causative economic factors and their various consequences. Unavoidable time lags or deliberate delay actions are common enough in engineering control theory, and the methods presented by Professor Tustin for analysing their effects in economics are among the most directly valuable features of his book. He fully realises, on the other hand, that the very long-term problems, based on uncertain data, may call for dubious extrapolation, or demand the solution of a large number of generally similar systems differing with respect to assumed values of influential factors considered singly and in combination. The mathematical labour thereby involved might well take so long that economic depression would actually come about before the anticipatory measures that might have prevented it could be discovered and put into effect.

Here, evidently, exists an enormous potential field for the use of electrical computers, which Professor Tustin very rightly emphasises. He gives a brief account of representative types of analogue computers and simulators that have come into use in engineering for the study of complex systems, especially such as involve non-linear relations. From this descriptive matter he proceeds to outline the main requirements of

an analogue computer for economic prediction, noting that it would need to embody means for temporarily arresting the passage of "time" in order that changes representing, for instance, hypothetical economic disturbances or policy variations, may be injected at any desired stage.

A principal use for such an analogue, and for the control system methods of analysis which Professor Tustin has established, would be to investigate a reliable presentation of any contemporary state of a national economy, and thence to formulate guiding rules of government action intended to introduce automatic stability. From this standpoint alone, Professor Tustin's book justifies most careful attention by economists, to whom it may introduce new concepts no less than new and powerful technical tools. For engineers and electronic control technologists it will prove a rewarding study, not least by pointing to ways in which their special knowledge can be increasingly useful within the economic system in which they are important shareholders.

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BRITISH STANDARDS

The following publications have been issued by the British Standards Institution. Copies are available from the Sales Department of the Institution, 2 Park-street, London, W.1, at the price given after each title.

Copper-Alloy Globe Valves (for General Purposes). (4*s*., post free.)

The first of a series of British Standards for copper-alloy valves for general purposes has been issued. It covers globe valves and is designated B.S.2060. Requirements for rating, design and manufacture, materials, dimensions, tests and marking are specified for angle and oblique (or "Y") valves with rising stem, inside or outside screw, flanged or screwed ends and of classes 100, 125, 150, 200 and 250 which represent their respective primary service pressure ratings as determined in a manner set out in the specification. The nominal sizes of the valves range from ¼ in. to 3 in. The present series is to be followed by other series for ferrous metal valves for general engineering use.

Ferrous Pipes and Piping Installations (For and in connection with Land Boilers). (10*s*. 6*d*., post free.)

First published in 1938 and revised in 1942, a third edition of B.S. 806 has been issued. It applies to the design and construction of ferrous metal pipework connecting a land steam boiler to an engine, turbine or industrial plant and all auxiliary pipework in connection therewith. The pipes and pipe fittings forming parts of such installations for (*a*) pipes of any bore where the pressure exceeds 50 lb. per square inch and (*b*) pipes of over 10-in. bore for steam at pressures up to and including 50 lb. per square inch, are also covered. The Standard does not apply to the use of carbon steel where the temperature exceeds 900 deg. F., or to the use of alloy steel where the temperature exceeds 975 deg. F. The scope of the specification has been extended to provide for developments which have taken place in pipework-installation practice, notably in the use of alloy steels. Material specifications are included for: Class A, cold-drawn seamless carbon-steel pipes; classes B and C, hot finished seamless carbon-steel pipes; class D, hydraulic lap-welded carbon-steel pipes; class E, roll lap-welded carbon-steel pipes; class F, butt-welded carbon-steel pipes; class M, cold-drawn seamless molybdenum-steel pipes; class P, cold-drawn seamless chromium-molybdenum steel pipes; class Q, hot-finished seamless chromium-molybdenum steel pipes; and iron, carbon steel and molybdenum-steel castings. Various sections of the Standard deal with design requirements, the procedure to be observed in the manipulation and fabrication of alloy-steel pipes; and constructional data, including the attachment of flanges. Some informative appendixes are included.

Dimensions of Diamond Abrasive Wheels and Tools. (4*s*., post free.)

A new Standard, B.S. 2064, covering the dimensions of diamond abrasive wheels and tools, constitutes another publication in the series for diamond tools for the engineering industry. It specifies dimensions and tolerances for peripheral, straight-cup, double-cup, taper-cup and bull-nosed cup wheels; dish, cut-off and chip-breaker wheels; and milling tools, hollow drills, stone saws and hones, all in resinoid, vitrified and metallic bonds.

TRADE PUBLICATIONS

Lighting Fittings. The General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2, have selected a "basic range" from their lighting fittings which will be kept in stock at all depots. The first two lists issued cover decorative and commercial fittings for filament lamps.

Heating and Process Steam. A booklet issued by Spirax-Sarco, Ltd., Cheltenham, Gloucestershire, describes methods of improving efficiency and economy in the use of steam for heating or processing. A complete steam circuit is considered and devices that are available to improve the quality of the steam at each stage are listed. These include: thermostats, blenders, strainers, water-traps, steam traps, air extractors and vents, drain traps and economisers.

Air Conditioning. A leaflet issued by the Dravo Corporation, Dravo Building, Pittsburgh 22, Pa., U.S.A., describes their air-conditioning plant designed for control rooms and similar situations. Two sizes of evaporator are listed, for either floor or ceiling mounting, and five sizes of condenser, either air or water cooled. Evaporator and condenser units are connected on site.

Variable Capacitors. The Plessey Co., Ltd., Ilford, Essex, have issued a catalogue (for manufacturers only) of their range of variable capacitors. Full details of their operating characteristics and curves of capacitance against rotation are given for each type.

Portable Flame Cutter. Leaflets giving full particulars of their "Quicky" portable flame-cutting machine, have been issued by the Oxhycarbon Co., Ltd., 6 Hainthorpe-road, West Norwood, London, S.E.27. The machine is motor driven and will make straight or circular cuts in steel up to 2½ in. thick.

Industrial Solenoids. A booklet published by Oliver Pell Control, Ltd., Cambridge-row, Burrage-road, Woolwich, London, S.E.18, describes their range of "Varley" industrial solenoids. There are types for either alternating or direct current supplies, with pulls ranging from 1 oz. to 1,200 lb.

Crude-Gas Valve. We have received from D.M.M. (Machinery), Limited, 66 Victoria-street, S.W.1, a leaflet describing the crude-gas valves of the sliding-plate type as made by Zimmermann and Jansen, G.m.b.H., Dueren, Western Germany. This type of valve utilises a power-operated sliding plate together with an axially-movable sealing-ring held against it by compressed air and is stated to give perfect sealing.

Cementation Processes. The Cementation Company, Limited, Doncaster, has sent us a well-illustrated booklet describing the uses to which their processes may be put. These have progressed from the sealing of water-carrying rock-fissures to the consolidation of alluvial deposits and rock-strata and to the repair of masonry structures and their foundations. A section of the booklet lists numerous works carried out in many parts of the world.

Industrial Brushes and Wheels. A catalogue published by W. Canning & Co., Ltd., Great Hampton-street, Birmingham, 18, lists their range of brushes for all industrial purposes. Scratch brushes, hand and wheel types, polishing wheels, paint brushes and pencil brushes are all included.

Castings, Crushers and Colour-Printing Machinery. A leaflet received from Armstrong Whitworth, Ltd., Close Works, Gateshead-on-Tyne, 8, describes, with the aid of three-dimensional illustrations, "Kue Ken" jaw and gyratory crushers, multi-colour Rotogravure printing machinery and the Beier steplessly-variable gear, the action of which depends on the drag of an oil film. In the same leaflet attention is drawn to the steel castings made by Jarrow Metal Industries, Ltd., Western-road, Jarrow-on-Tyne, Durham.

Outsize and Special-Purpose Bearings. Ball and roller bearings of unusual design and ranging in size from 4 in. bore to 120 in. outside diameter are made by the Kaydon Engineering Corporation, Muskegon, Michigan, who have issued a pamphlet showing in section and full size a variety of ways in which bearings and races may be arranged for special purposes. The Kaydon Corporation make large, lightweight and thin-section bearings and have developed a surface hardening technique, which permits the raceways to be drilled, tapped and gear-cut before it has been applied.

Contactors. A descriptive leaflet of their contactors has been issued by Benson and Robinson, Ltd., 6 Government Buildings, Kidbrooke Park-road, London, S.E.3. Three models are described, the heaviest of which has contacts rated for 150 amperes at 24 volts. Up to four main and two auxiliary contacts can be fitted.

BOOKS RECEIVED

Yielding Props. Part II: Laboratory Trials of the G.H.H. Friction Prop, Type D.R. By W. H. EVANS and S. G. HARRIS. Ministry of Fuel and Power, Safety in Mines Research Establishment, Research Report No. 84. *Technical Information Section, Safety in Mines Research Establishment, Portobello-street, Sheffield.* (9*d*.)

Index of Publications of the Road Research Laboratory, January, 1933, to June, 1953. Published for the Department of Scientific and Industrial Research by *H.M. Stationery Office, Kingsway, London, W.C.2.* (1*s*. 9*d*.)

Higher Transcendental Functions. In two volumes. Based, in part, on notes left by HARRY BATEMAN. Compiled by the Staff of the Bateman Manuscript Project. *McGraw-Hill Book Company, Incorporated, 330 West 42nd-street, New York 36, N.Y., U.S.A.*, and *McGraw-Hill Publishing Company, Limited, 95 Farringdon-street, London, E.C.4.* (Volume I, 52*s*.; Volume II, 60*s*.)

British Plastics Year Book 1954. A Classified Guide to the Plastics Industry. Twenty-fourth edition. *Iliffe and Sons, Limited, Dorset House, Stamford-street, London, S.E.1.* (30*s*.)

Report on the Derailment which occurred on 8th August, 1953, near Abington, in the Scottish Region, British Railways. Ministry of Transport and Civil Aviation. Railway Accidents. *H.M. Stationery Office, Kingsway, London, W.C.2.* (2*s*. 6*d*.)

Business, Legal and Ethical Phases of Engineering. By D. T. CANFIELD and J. H. BOWMAN. Second edition. *McGraw-Hill Book Company, Incorporated, 330 West 42nd-street, New York 36, N.Y., U.S.A.* (6 dols.); and *McGraw-Hill Publishing Company, Limited, McGraw-Hill House, 95 Farringdon-street, London, E.C.4.* (48*s*.)

How to Estimate. Appendix of Cost Adaptation Tables and Percentages. Compiled by A. E. BAYLIS. Appendix to the eleventh edition of **How to Estimate** by J. T. REA. *B. T. Batsford, Limited, 4 Fitzhardinge-street, London, W.1.* (3*s*. 6*d*.)

The Manufacture and Properties of Steel Wire. By ANTON POMP. Translated from the German by C. P. BERNHOEFT. *The Wire Industry, Limited, 33 Furnival-street, London, E.C.4.* (84*s*.)

Fire Hazard of Internal Linings. By D. HIRD and C. F. FISCHL. National Building Studies Special Report No. 22. Published for the Department of Scientific and Industrial Research by *H.M. Stationery Office, Kingsway, London, W.C.2.* (1*s*. 3*d*.)

The Royal Society of Arts, 1754-1954. By DEREK HUDSON and KENNETH W. LUCKHURST. *John Murray (Publishers), Limited, 50 Albemarle-street, London, W.1.* (30*s*.)

Department of Scientific and Industrial Research Report for the Year 1952-53. *H.M. Stationery Office, Kingsway, London, W.C.2.* (8*s*.) (Reviewed in ENGINEERING, March 26, 1954, page 386.)

Manual for Plastic Welding. Volume II: Polyethylene. By G. HAIM and J. A. NEUMANN. *Crosby Lockwood and Son, Limited, 39 Thurloe-street, London, S.W.7.* (30*s*.).

Étude et Tracé des Écoulements Permanents en Canaux et Riviéres. By R. SILBER. *Dunod, 92, Rue Bonaparte, Paris 6e.* (1800 francs).

Riementriebe – Kettentriebe – Kupplungen. *Friedr. Vieweg und Sohn, Braunschweig, Burgplatz 1, Germany.* (24·50 *D.M.*)

Jahrbuch der Hafenbautechnischen Gesellschaft. Zwanzigster und einundzwanzigster Band, 1950-1951. *Springer-Verlag, Reichpietschufer 20, Berlin, W.35.* (60 *D.M.*)

Wasseraufbereitung im Dampfkraftbetrieb. By DR. A. SPLITTGERBER. *Springer-Verlag, Reichpietschufer 20, Berlin, W.35.* (48 *D.M.*)

Treibstoffe für Verbrennungsmotoren. By FRANZ SPAUSTA. *Springer-Verlag in Wien 1, Mölkerbastei 5.* (92*s*.)

Die Kristallisation in der Verfahrenstechnik. By GÜNTHER MATZ. Springer-Verlag, Reichpietschufer 20, Berlin, W.35. (22·50 *D.M.*).

HIGH-TEMPERATURE STEAM PIPES

PROPERTIES OF STEELS AND BASIS OF DESIGN

*By P. H. Margen,** B.SC.(ENG.), A.M.I.E.E.

Power stations are now being built in Britain for steam temperatures of 1,000 deg. and 1,050 deg. F., and even higher temperatures are already in use elsewhere. New alloys are constantly being developed to deal with the more onerous conditions, yet the present British Standard Piping Code, B.S. 806 : 1954† covers only carbon steel up to 900 deg. F., and two additional low-alloy steels up to 975 deg. F. Such codes are clearly of no help to the designer of the new high-temperature piping systems.

American codes which do deal with higher temperatures, do not include some of the most promising British steels such as the molybdenum-vanadium, and may also be based on different plant life and reliability concepts. They, too can, therefore, be only a limited guide to British designers.

The problem is, of course, not an easy one. The leading authorities on the subject differ in their recommendations as to whether creep strain, creep rate or rupture data shall be the basis of design and as to whether or not – or to what extent – creep ductility should be taken into consideration. Test results for the new materials become available first of all from relatively short-term tests and extrapolations made from these may require adjustment as tests of longer duration are completed. Properties of steels are improved by developments in heat treatment or modifications in the composition.

Yet the difficulties imposed by these changing conditions make it all the more important to communicate to the industry at frequent intervals an authoritative guide to up-to-date design practice. In order to attain this, agreement must first of all be reached on a framework whereby the allowable working stresses can be computed from the available test data, particular emphasis being placed on the appropriate tolerances for extrapolation errors, quality variations, etc.

It is the object of the present article to discuss the form which such a framework might take. In the course of the discussion, the properties of the main high-temperature pipe steels are reviewed, and the suggested working stresses are applied to problems of design.

* The author is with Messrs. Kennedy and Donkin, London.

† See page 456.

CREEP STRAIN, CREEP RATE OR RUPTURE

At high temperatures, the limit to the stresses which can be allowed in metal components is set by "creep," i.e., the gradual deformation of the metal in the direction of the stress followed eventually by fracture. To avoid undue deformation or to prevent fracture, it is customary to specify that the working stress shall not exceed one or more of the following values:

(*a*) The tensile stress expected to produce a given creep strain in the scheduled plant life ;

(*b*) the tensile stress to produce a given creep rate after a specified time interval;

(*c*) a fraction $\frac{1}{F}$, of the tensile stress expected to cause rupture in the scheduled plant life, where F may be termed the "rupture safety factor."

In the 1952 A.S.M.E. boiler code, limits (*b*) and (*c*) are stated to have been employed,* while in B.S. 806, limits (*a*) and (*c*) appear to have been used.* R. W. Bailey, in a 1951 paper, recommended that only limit (*a*) should be used, but that three design creep strains be selected for low, medium and high creep ductility steels respectively.

The need to specify limit (*a*) or, alternatively,† limit (*b*), for precision components such as parts of steam turbines is self evident. Steam pipes, however, are not precision components – they move appreciably during normal thermal expansion and contraction, and there is no difficulty in accommodating any increase in diameter caused by creep. The longitudinal creep induced by internal pressure is negligible, while creep induced by thermal stresses is actually beneficial in that it tends to relieve the expansion stresses in the hot condition.

It follows from this discussion that creep deformation of steam pipes is not, in itself, a cause of concern, the only concern being avoidance of fracture. It remains to examine whether limits (*b*) and (*c*) are of any value in this respect.

Practical conditions can be more severe than those represented by the simplified design formulæ which are based on the internal fluid pressure only. For instance pipe supports and thermal expansion can be responsible for supplementary stresses; surface damage, non-metallic inclusions, and weld deformations can cause local stress concentrations in the material; and the rupture strength of the steel is subject to quality variations and extrapolation errors. To avoid failure when conditions are unfavourable in

* In the creep range the lowest of the following was used: (i) the stress to produce a creep rate of 10^{-5}; (ii) 60 per cent. of the average 100,000-hour rupture stress ; (iii) 80 per cent. of the minimum 100,000-hour rupture stress.

* The specified working stress for carbon-molybdenum steel is identical with the stress for 0·1 per cent. creep in 100,000 hours estimated by H. J. Tapsell and R. W. Ridley (1946); that for carbon steel is appreciably less than the stress for 0·1 per cent. creep in 100,000 hours and appears to correspond to a rupture safety factor of about 1·7 for 100,000 hours.

† Limit (*b*) is usually regarded as an approximate method of finding the long-term creep strain from relatively short-term tests.

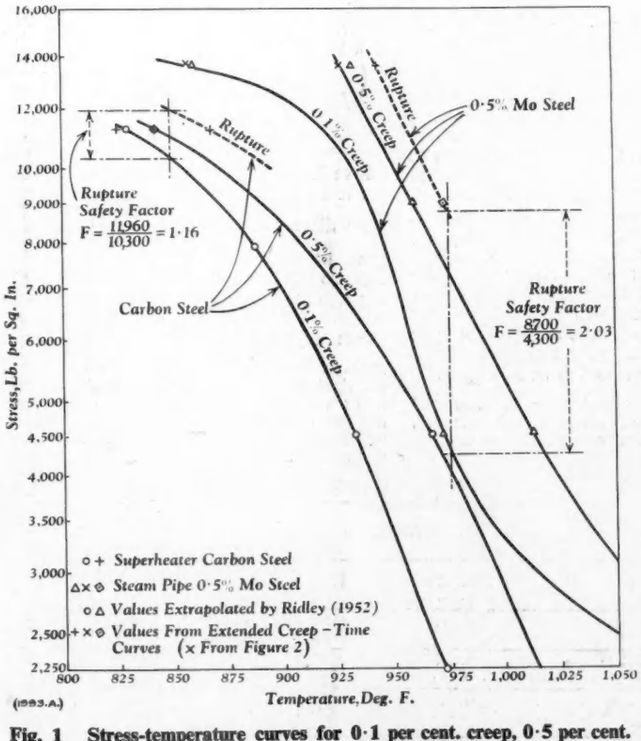
Stress, Lb. per Sq. In.
Temperature, Deg. F.
Rupture
0·1% Creep
0·5% Creep
0·5% Mo Steel
Rupture Safety Factor F = 11960/10,300 = 1·16
Rupture Safety Factor F = 8700/4,300 = 2·03
Carbon Steel
o + Superheater Carbon Steel
Δ × ◇ Steam Pipe 0·5% Mo Steel
o Δ Values Extrapolated by Ridley (1952)
+ × ◇ Values From Extended Creep – Time Curves (× From Figure 2)
(1993.A.)

Fig. 1 Stress-temperature curves for 0·1 per cent. creep, 0·5 per cent. creep and rupture in 100,000 hours.

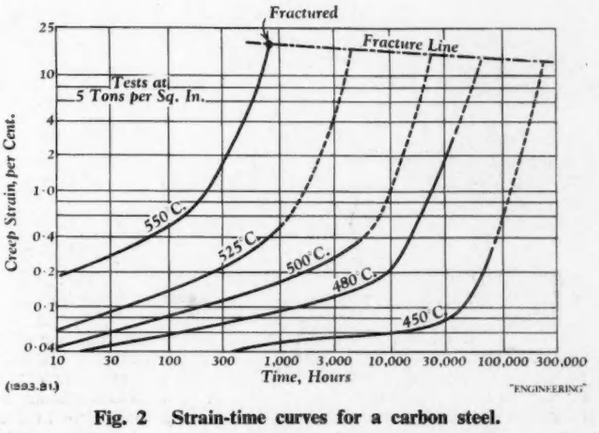

Fig. 2 Strain-time curves for a carbon steel.

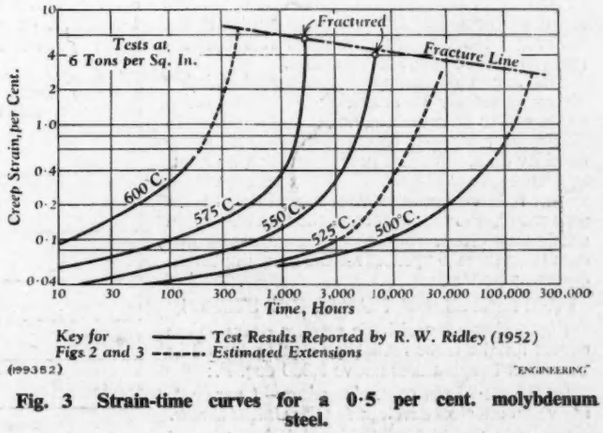

Fig. 3 Strain-time curves for a 0·5 per cent. molybdenum steel.

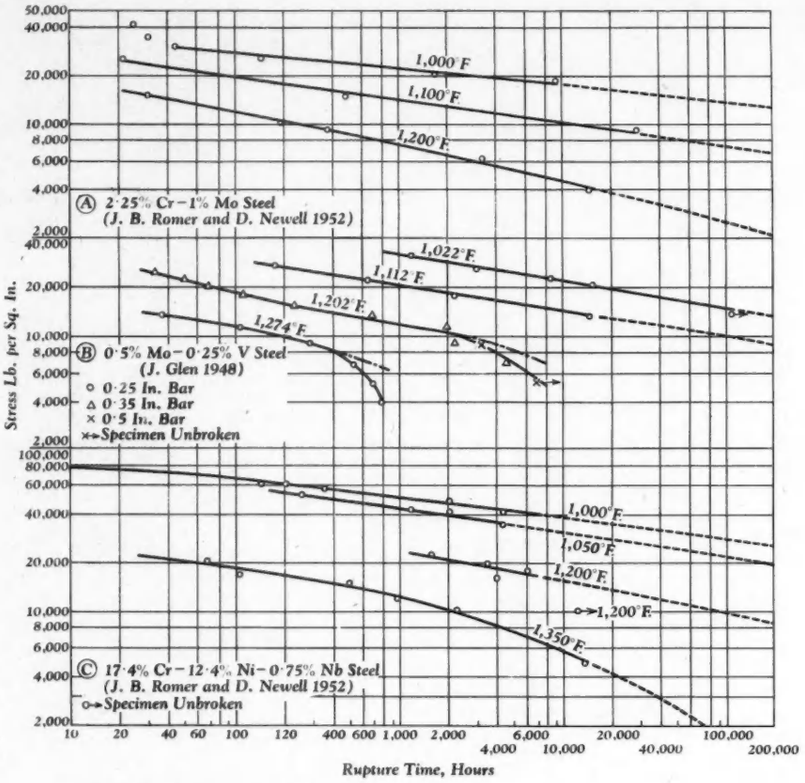

Fig. 4 Rupture stress-time curves for high-grade steels.

respect of a number of the points listed above, the material must be capable of withstanding without failure, stresses larger than the allowable working stress. Neither limit (*a*) nor (*b*) can throw any light on the capacity of the material to withstand such excess stresses, for in neither case is the material tested to destruction. For example, the data presented in Table I, which are supported by Figs. 1, 2 and 3, suggest that steels designed for 0·1 per cent. creep may rupture with an excess stress as low as 16 per cent. or as high as from 100 per cent. to 200 per cent. depending on the type of steel, the temperature and the service life. Clearly 16 per cent. reserve would be unsafe and 100 per cent. to 200 per cent. would be excessive so that limit (*a*) is of no help in producing a safe and yet reasonable design. Recourse should, therefore, be had to limit (*c*) which, being based on tests to destruction can assure a selected reserve with respect to the average condition of failure. As discussed later, the magnitude of the reserve needed depends on various service conditions and on secondary properties of the steels, such as the standard deviation from the average rupture strength, and the creep ductility (which influences the degree to which stress concentrations can be relieved by creep).

The above discussion suggests that existing piping codes err in attaching weight to creep strain and creep rate data, i.e., that design should be based only on rupture stress and creep ductility data. A third property which becomes important at very high temperatures is corrosion, as this reduces the effective sectional area of the pipe metal, and thus increases the true stress and accelerates creep. Subsequent paragraphs discuss these three properties for the most important current pipe steels.

PROPERTIES OF MAIN PIPE STEELS

Fig. 4 shows logarithmic rupture stress – time curves for the three main pipe steels adopted in Britain at temperatures above 1,000 deg. F.:

(*a*) The 2·25 per cent. chromium – 1 per cent. molybdenum steel developed in the United States.

(*b*) The 0·5 per cent. molybdenum – 0·25 per cent. vanadium steel first applied at Battersea generating station in the "nineteen thirties," and now used with an improved heat treatment.*

(*c*) A stabilised austenitic steel of the approximate composition 18 per cent. chromium – 13 per cent. nickel – 1 per cent. niobium, which has been developed both in Britain and in the United States.

The curves in Fig. 4 are extrapolated to 200,000 hours which is a reasonable expectation of the steaming life of base load generating stations, namely, 33 years at 70 per cent. steaming-duty factor. As the longest published test results for the three steels cover 30,000, 110,000 and 15,000 hours respectively, the extrapolations to 200,000 hours must be regarded with reserve in the case of the first and last of these steels. The results, which are compared in Fig. 5, are, however, sufficient to establish that the 200,000-hour rupture strength of the steels increases in the order: (1) 2·25 per cent. Cr–1 per cent. Mo, (2) 0·5 per cent. Mo–2·25 per cent. V, (3) 18 per cent. Cr–13 per cent. Ni–1 per cent. Nb, the approximate ratio being 0·82 : 1·0 : 1·6 at 1,050 deg. F. Rupture stresses for three lower grade steels are also shown in Fig. 5.

* Tempered for 5 hours at 690 deg. F. The steel now also contains from 0·25 per cent. to 0·5 per cent. chromium, but this does not affect the rupture strength.

The gradients of the curves in Figs. 4 and 5 indicate that the rupture strength of most pipe steels is halved by an increase in temperature of the order of 100 deg. F., and that it is reduced by about one sixth when the scheduled life is doubled. When the change in the effective specimen section produced by creep and corrosion is appreciable, suitable corrections should be applied to the test results.

It is of interest that the creep ductility of the three high-grade pipe steels varies in the inverse order to their rupture strength, 2·25 per cent. Cr-1 per cent. Mo, being the steel with the highest creep ductility, and 18 per cent. Cr-13 per cent. Ni-1 per cent. Nb, that with the lowest. At one time 0·5 per cent. Mo-0·25 per cent. V steel had been regarded as a low creep ductility steel, but J. Glen (1948) has shown since that tempering increases the creep ductility to more than 9 per cent. over the practical range of design conditions. The improvement caused by tempering is brought out clearly by the creep ductility contours in Figs. 6 and 7. Fig. 6 shows data obtained by H. J. Tapsell, C. A. Bristow and C. H. M. Jenkins in 1951, for un-tempered 0·5 per cent. Mo, 0·25 per cent. V steel and Fig. 7 data obtained by J. Glen in 1948, for a tempered steel of this type.

Published data by J. T. Agnew, G. A. Hawkins and H. L. Solberg, and also by J. Glen indicate that the penetration varies approximately as $(\text{time})^{0\cdot4}$, is doubled by about 50 deg. F. temperature increase, and is reduced by about 90 per cent. (at 1,200 deg. F.) when 10 per cent. chromium is added to the steel. At lower temperatures chromium has less effect.

From the aspect of creep, it is the mean effective penetration during the life of the component which is relevant, and this amounts to about 0·7 times the final penetration. Allowing for internal and external pipe-wall corrosion, about 1·4 times the 200,000 hour penetration should thus be added to the wall thickness in order to counteract corrosion. Fig. 8 shows this allowance plotted against temperature for steels with various chromium contents. The graph indicates that corrosion becomes appreciable with low chromium content steels above 1,050 deg. F.

DESIGN FORMULA

It is shown in Appendix I that a pipe of external diameter, D, and wall thickness, t, submitted to an internal fluid pressure, P, will rupture due to creep in the same time as a tensile test specimen submitted to the stress:

$$S_r = \frac{R\,P\,(D - 2\,k\,t)}{2\,t}, \quad . \quad (1)$$

where R is a factor less than unity which depends on test properties of the material* but not the pipe dimensions, $k = \left(1 - \frac{m}{2\,n}\right)$, m being the gradient of log time – log strain curves near the rupture point, and n the gradient of log time – log rupture stress curves.

* R may be defined as $\frac{S_p}{S_r}$ where S_p is the primary stress in a complex stress system in which the three principal stresses are in such ratios that no deformation takes place along the secondary axis; and S_r is the stress for a test in pure tensions which causes rupture in the same time as the complex stress system referred to above.

TABLE I. RUPTURE SAFETY FACTOR AFFORDED BY DESIGN FOR 0·1 PER CENT. CREEP

Steel	Investigator		Time Hours	Temperature deg. F.	$\frac{S_r}{S_{0\cdot1}}$ †
Carbon	R. W. Ridley	AE*	100,000	850	1·16
0·5 per cent. Mo	R. W. Ridley	AE	100,000	975	2·03
0·5 per cent. Mo—0·25 per cent. V	J. Glen	E	100,000	967	1·50
0·5 per cent. Mo—0·25 per cent. V	J. Glen	T	2,700	1,112	1·90
19 per cent. Cr—14 per cent. Ni—1·7 per cent. Nb	D. A. Oliver and	T	3,000	1,202	2·85
19 per cent. Cr—14 per cent. Ni—1·7 per cent. Nb	G. T. Harris	T	3,000	1,112	1·57
25 per cent. Cr—15 per cent. Ni	W. E. Bardgett and	T	1,000	1,202	1·72
25 per cent. Cr—15 per cent. Ni	G. R. Bolsover	T	1,000	1,292	4·5

* AE = Extrapolations made by author. (See Figs. 1, 2 and 3). E = Extrapolations made by investigator. T = Test Results.
† S_r = Stress to Rupture. $S_{0\cdot1}$ = Stress to produce 0·1 per cent. Creep.

Typical values of m and n are 0·5 and 6 respectively, so that k becomes 0·96, or, for practical purposes, 1·0. The right-hand side of equation (1) can then be replaced by $\frac{R P d}{2 t}$ where d is the internal pipe bore.

If it is desired to design for a fraction $\frac{1}{F_r}$ of the stress to rupture the pipe in the scheduled life, then the minimum wall thickness, t_m, should accord with the following expression:

$$t_m = \frac{P D}{2 (S + k P)} + C, \quad . \quad . \quad (2)$$

where S = " working " or design stress $= \frac{S_r}{F}$

. . . (3)

S_r = stress to rupture a tensile specimen in the scheduled pipe life,

F = nominal rupture safety factor (= product of actual rupture safety factor, F_r, and the stress system factor, R).

C = allowance for mechanical strength, corrosion, etc.

Equation (2) is in the form adopted by most piping codes, though various values of k are used. Thus B.S. 806 and the old A.S.M.E. boiler codes used $k = 0$, which is undoubtedly too low, i.e., produces excessive wall thicknesses for pipes having high thickness/diameter ratios (for example, pipes serving at high pressures and temperatures, particularly when made from the lower-grade steels). The 1949 A.S.M.E. boiler code increased k to 0·4, and the 1952 code made a further increase to 0·7 for pipes above a certain temperature.* The values are thus beginning to approach the value $k = 1$, namely that recommended in this article for high temperature applications.

Current piping codes show the allowable working stress, S, for each steel at various temperatures, but take a constant corrosion and mechanical strength allowance, such as C = 0·04 in. (B.S. 806) and C = 0·065 in. (A.S.M.E. code). The large variations in the corrosion for different steels and temperatures make it desirable to change this practice, i.e., to specify the particular value of C for each steel and temperature in the same way as the allowable stress.

* 1,000 deg. F. for ferritic steels and 1,150 deg. F. for austenitic steels.

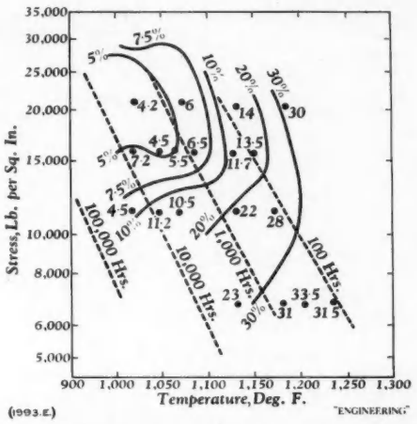

Fig. 6 Creep ductility-test data and estimated contours. Untempered 0·5 per cent. Mo, 0·25 per cent. V steel: data by H. J. Tapsell, C. A. Bristow and C. H. M. Jenkins in 1951.

It is suggested that C may be taken as 0·04 in. plus 1·4 times the expected penetration in 200,000 hours, and that it be obtained from Fig. 8.

RUPTURE SAFETY FACTOR

Equations (2) and (3) bring out the main steel properties which affect the minimum permissible wall thicknesses of pipes, i.e., the influence of rupture strength and resistance to corrosion. A number of secondary factors also have a bearing on the desirable wall thickness, and these can be allowed for by making appropriate adjustments to the nominal rupture safety factor, F.

One or two of these factors have a favourable bias, notably the fact that the complex stress system in a pipe under pressure is less severe than if only the circumferential stress existed, as indicated by the fact that the stress system factor, R, in equation (1) is less than unity. A large number of factors have an unfavourable bias, such as the presence of stress concentrations in the material, the presence of stresses caused by factors other than internal pressure, and the influence of short-term pressure and temperature peaks when design is based on the mean steam conditions.

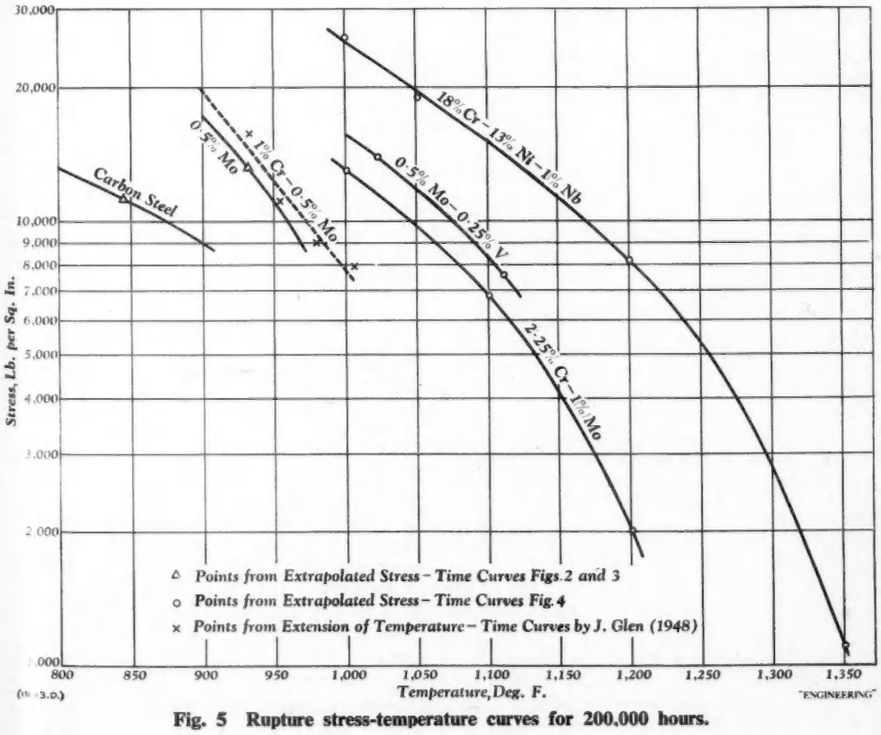
Stress, Lb. per Sq. In.
Temperature, Deg. F.
Carbon Steel
0·5% Mo
1% Cr–0·5% Mo
18% Cr–13% Ni–1% Nb
0·5% Mo–0·25% V
2·25% Cr–1% Mo
Points from Extrapolated Stress–Time Curves Figs. 2 and 3
Points from Extrapolated Stress–Time Curves Fig. 4
Points from Extension of Temperature–Time Curves by J. Glen (1948)
"ENGINEERING"

Fig. 5 Rupture stress-temperature curves for 200,000 hours.

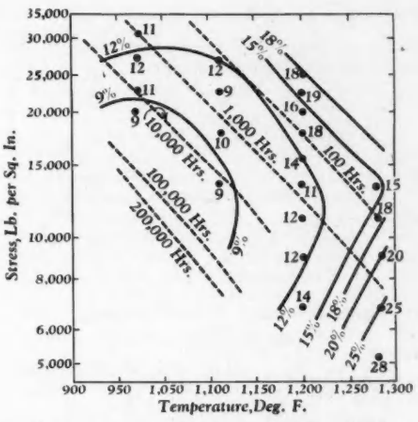

Fig. 7 Creep ductility-test data and estimated contours. Tempered 0·5 per cent. Mo, 0·25 per cent. V steel: data by J. Glen in 1948.

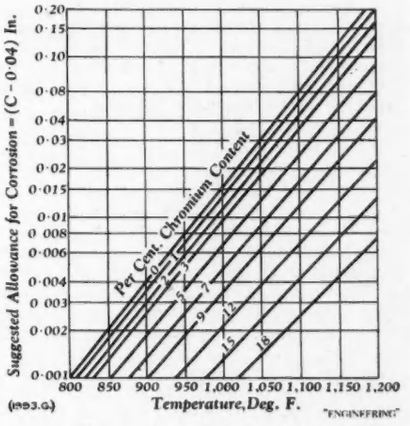

Fig. 8 Suggested allowance for corrosion.

A second type of factor is random, i.e., has no bias but can be favourable or unfavourable. For instance, the quality of steel of the same nominal composition and heat treatment can vary, extrapolations of properties from relatively short-term data can be at fault, the initial local stress concentrations in the material can be greater or less than those expected. In theory there is no limit to the magnitude which individual deviations from the expected conditions can reach, so that the engineer must be guided by probability concepts. These indicate that it is unlikely that the greatest unfavourable extrapolation errors will coincide with the presence of particularly bad casts, and with the presence of, say, surface damage. Consequently, allowances for individual random effects should not be summed arithmetically but rather be represented by a root mean square allowance.*

A reasonable expression for estimating the value of the nominal rupture safety factor, F, would thus be:

$$F = [(1 + a_1)(1 + a_2) \ldots] [1 + \sqrt{b_1^2 + b_2^2 + \ldots}], \quad . \quad (4)$$

where $a_1, a_2 \ldots$ are allowances for factors with a definte bias, $b_1, b_2 \ldots$ are allowances for random factors.

The values of the most importance of the individual allowances are discussed in the next section.

* If distributions having standard deviations σ_1, σ_2, etc., are summed, then the resulting distribution has a standard deviation equal to the root mean square value of σ_1, σ_2, etc. B.S. specifications, for instance, now provide for various independent instrument tolerances to be summed by the root mean square method.

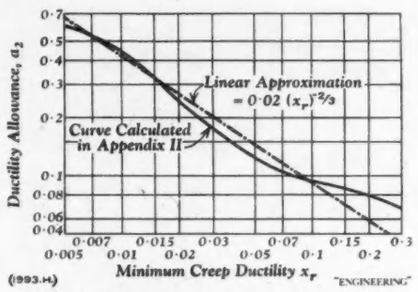

Fig. 9 Ductility allowance in for mulafor rupture safety factor.

ALLOWANCE FOR PRESSURE AND TEMPERATURE DEVIATIONS FROM MEAN VALUES

Moderate deviations in pressure and temperature from the mean annual values have little influence on creep, since the effect of positive and negative deviations nearly cancel out. Hence the " design pressure," P, and " design temperature," Θ, may be defined as the mean pressure and temperature maintained in each twelve months operating period, and the effect of deviations from the mean conditions may be dealt with by an appropriate allowance, a_1 in the expression for the rupture safety factor.

On the assumption that creep recovery can be neglected* the allowance is given by:

$$(1 + a_1) = \left\{ \Sigma h \left(\frac{p}{P}\right)^n + [1 + \Sigma h g (\theta - \Theta)]^n \right\}^{\frac{1}{n}}, \quad . \quad (5)$$

where p and θ denote the instantaneous pressure and temperature maintained for the fractional time, h, n = gradient of the log time-log rupture stress curve, and g = gradient of the log rupture stress-temperature curve (fraction of stress per deg. F).

Table II shows an approximation to a typical operating cycle, containing pressure deviations of magnitude α per unit P, and temperature deviations of magnitude β deg. F. which on some occasions coincide. For that cycle, equation (5) reduces to:

$$a_1 = 0{\cdot}25\,(n-1)\,(\alpha^2 + g\,\alpha\,\beta + g^2\,\beta^2), \quad (6)$$

if terms containing the fourth and higher powers of the small quantities α and $g\,\beta$ are neglected.

The turbine specification, B.S.132, recommends that " normal " deviations from the mean steam conditions at the turbine stop valve shall not exceed 10 per cent. of the pressure and 15 deg. F. temperature, nor shall " abnormal " deviations exceed 20 per cent. of the pressure for more than 12 hours, 25 deg. F. temperature for more than 400 hours, and 50 deg. F. temperature for more than 80 hours in each 12 months of operation. For typical operation conforming with these requirements the equivalent values of α and β would be approximately 0·1 and 20 deg. F., respectively. The expression then reduces to:

$$a_1 = (n-1)\,(0{\cdot}0025 + 0{\cdot}5\,g + 100g^2). \quad (6a)$$

* The experiments by A. E. Johnson and N. E. Frost (see ENGINEERING, vol. 175, pages 25, 53 and 249, 1953) on creep of three pipe steels under cyclic stress and various temperature conditions give results in reasonable agreement with those calculated on the assumption that creep recovery is negligible for the cyclic conditions encountered in operation. The tests by P. C. Herbert and D. J. Armstrong (see ENGINEERING, vol. 175, page 605, 1953) on a Nimonic alloy suggest that complete shut downs do not affect the rupture times.

The values of g and n may be obtained, respectively, from the gradients of the curves in Fig. 5, and from the inverse of the gradients of the curves in Fig. 4. The values of the allowance, a_1 calculated for 2·25 per cent. Cr-1 per cent. Mo steel, 0·5 per cent. Mo-0·25 per cent. V steel and 18 per cent. Cr-13 per cent. Ni-1 per cent. Nb steel at 1,050 deg. F. are, respectively, 0·063, 0·038 and 0·30.

TABLE II.—ASSUMED OPERATING CYCLE

Period	1	2	3	4	5	6	7
Duration (fraction of year) h	⅛	⅛	⅛	⅛	⅛	⅛	⅛
Pressure deviation $= \left(\frac{p}{P}\right) - 1{\cdot}0$	0	$+\alpha$	0	$+\alpha$	$-\alpha$	-0	$-\alpha$
Temperature deviation $(\theta + \Theta)$ deg. F.	0	0	$+\beta$	$+\beta$	0	$-\beta$	$-\beta$

TABLE III.—EXAMPLES OF ASSESSMENT OF REQUIRED RUPTURE SAFETY FACTOR
Working Stress and Minimum Pipe Wall Thickness

Symbol	Item	Steel: Carbon	0·5 per cent. Mo	1 per cent. Cr-0·5 per cent. Mo	2·25 per cent. Cr-1 per cent. Mo	0·5 per cent. Mo-0·25 per cent. V	18 per cent. Cr, 13 per cent. Ni-1 per cent. Nb
	*Design Conditions.**						
Θ	Temperature, deg. F.	805	905	905	1,055	1,055	1,055
P	Pressure, lb. per sq. in.	618	935	935	1,560	1,560	1,560
d	Pipe bore, in.	10	9	9	8·5	8·5	8·5
	Steel Properties.						
S_r	200,000 hour rupture stress, lb. per sq. in.	13,000	16,300	19,000	9,500	11,500	19,200
x_r	Minimum creep ductility	0·19	0·04	0·09	0·15	0·09	0·045
	Gradient of:						
g	log T_r-log S_r curve	7·5	6·6	4·4	7·5	5·0	5·5
n	log S_r-temp. curve, deg. F^{-1}	0·0045	0·0077	0·0100	0·0063	0·0063	0·0052
	Rupture Safety Factor Allowances.						
	(*a*) For bias:						
a_1	Press. and temp. deviations	0·045	0·068	0·060	0·063	0·038	0·030
a_2	Stress concentrations	0·061	0·172	0·099	0·071	0·099	0·157
a_3	Other causes	0·200	0·200	0·200	0·200	0·200	0·200
	(*b*) For random effects:						
b_1	Variable steel quality	0·10	0·10	0·10	0·12	0·14	0·10
b_2	Extrapolation errors, etc.	0·10	0·08	0·13	0·30	0·20	0·25
b_3	Stress concentrations†	0·05	0·14	0·08	0·06	0·08	0·13
b_4	Other causes	0·10	0·10	0·10	0·10	0·10	0·10
	Design.						
F	Rupture safety factor (from Eq. 4)	1·57	1·82	1·68	1·84	1·75	1·88
S	Allowable working stress, lb. per sq. in.	8,280	8,950	11,300	5,170	6,570	10,220
C	Corrosion allowance, in.	0·041	0·043	0·043	0·066	0·073	0·041
	Minimum Wall Thickness (in.)						
t_m	This article‡	0·417	0·517	0·420	1·364	1·100	0·696
t_m	B.S. 806: 1954	0·505	0·516	0·488	—	—	—
t_m	A.S.M.E. 1952	0·374	0·433	0·411	1·368	—	0·633

* Temperature taken 5 deg. F. more than turbine stop valve conditions to allow for temperature drop along pipe: pressure (P) taken 3 per cent. more than T.S.V. condition for 800 lb. per square inch and 4 per cent. more for other pressures except with B.S. 806 where an additional 9 per cent. has been allowed corresponding to usual safety valve settings.
† Taken as 0·8 times allowance a_2.
‡ All designs in this Table are in the " hot " range, i.e., are based on $k = 1{\cdot}0$.

THE EFFECTS OF STRESS CONCENTRATIONS AND CREEP DUCTILITY

Rupture tests are generally made on specimens of homogeneous material and smooth surface. In actual piping installations, however, one must expect the presence of small surface deformations, and non-metallic inclusions. When pressure is applied to the pipe, such irregularities result in stress concentrations, as shown by the theoretical work of H. Neuber (1933) on stress distributions around notches. Another source of initial stress concentrations are thermal deformations caused by welding, though these, to some extent, can be removed by stress relieving heat treatment.

In Appendix II it is shown that the effect of an initial stress concentration of magnitude r times the average stress level in the material, S_a, is to produce rupture in the same time as a uniform stress, $(1 + a_2)\,S_a$, where a_2 is a function of r, the creep ductility, x_r, and the shape of the notch or irregularity causing the stress deformation. For particular assumptions the full-line curve in Fig. 9 is calculated showing the type of effect of the creep ductility on the allowance a_2. The chain-dotted curve is a linear approximation to the full-line curve and has the equation:

$$a_2 = 0{\cdot}02\,(x_r)^{-\frac{2}{3}}. \quad . \quad (7)$$

In practice no published data exist on the values of the initial stress concentrations in commercial pipelines so that the numerical values of the allowance, a_2, and hence the precise effect of creep ductility of design can only be estimated. That the effect is significant is demonstrated by the failure of several low creep ductility molybdenum steels in service. R. W. Bailey (1951) has suggested an empirical segregation of steels into three classes according to their creep ductility, and the effect on design stresses of such a segretation would be somewhat similar to that of adopting the chain-dotted curve, Fig. 9.*

It is suggested that until more data become available Curve 2 be adopted for design. This is likely to result in safer designs than the complete avoidance of any creep ductility correction.

EFFECT OF BENDING STRESSES

A compressive axial stress, such as that caused on one side of the pipe by bending moments, increases the circumferential creep. Bending moments are caused by: (1) The weight of the pipe and the reaction of steam at bends. (2) Thermal expansion of the pipe. The axial stresses caused by (1) can be limited to reasonable values by restricting the spacing of pipe supports, thus a spacing of 28 ft. would produce a stress of about 0·2S, in a horizontal run of 9-in. bore, and S = 3 tons per square inch.

Stresses caused by (2) are gradually removed by creep, so that they disappear when the pipe is hot, and re-appear with opposite signs when the pipe is cold. The creep which has taken place

* R. W. Bailey based design on the stress to produce a specified creep strain in 100,000 hours, and used three different values of strain for low creep ductility, medium creep ductility and high creep ductility steels.

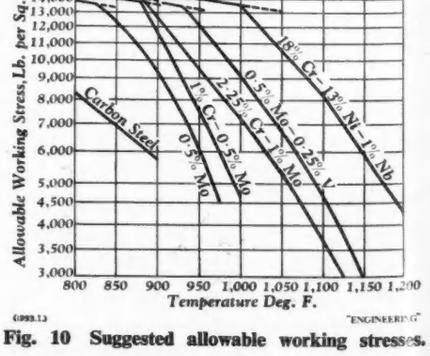

Fig. 10 Suggested allowable working stresses.

before this stress removal is completed, however, shortens the life of the pipe, and for that reason it is desirable to produce the stress-free condition at the outset by applying approximately 100 per cent. cold spring when the pipe is being installed.

RANDOM FACTORS

The problem set by random factors is illustrated by Fig. 9, which shows an assumed distribution of the frequency of failure against the term:

$$F_b = \frac{F}{[(1 + a_1)(1 + a_2) \ldots]},$$

i.e., the rupture safety factor corrected for all suspected bias.

The optimum design point is that for which the expected risk of failure is sufficiently small to conform with the following relation:

$$A = f B F_b, \quad . \quad . \quad (8)$$

where A = total cost of pipe metal, B = equivalent cost of failure or replacement, f = frequency of failure per σ and σ = standard deviation of the distribution of F_b.

If one could be certain at all times to forestall failure by replacement, then B would be the cost incurred by the premature pipe replacement, and the problem of selecting the appropriate safety factor would then be purely an economic study. Thus if B were equal to 2A, σ were 0·06 and the distribution were "normal," then the appropriate value of F_b would be 1·14.

In practice, failure cannot always be forestalled even if a record is maintained of the metal extension at several selected points of the run. In consequence more difficult personal issues are introduced in evaluating B, similar to those met by road authorities in determining whether particular safety projects can be justified. A further difficulty is that the data from which a frequency distribution might be constructed are few and not easily interpreted.

One random factor which should lend itself readily to statistical analysis, is the variation in the quality of steel of a given nominal composition and heat treatment. More difficult is the problem of assessing the degree of error which might be introduced by extrapolating relatively short-term test results to give the estimated behaviour for the full service life.

Inevitably the final choice relies largely on personal judgment, though a more objective method might be feasible when more long-range data for different steels have become available. The problem of estimating the extrapolation tolerance will never disappear entirely, as, by the time test data for a particular steel are available for the whole scheduled piping life a better steel has invariably been developed.

A British Standard Committee was formed in 1950 to recommend extrapolated rupture and creep stresses for particular steels. Such a committee would also be in the best position to assess the tolerances for quality variation and extrapolation errors.

ALLOWABLE WORKING STRESSES

Table III shows a tentative allocation of allowances in accordance with the preceding discussion, and the resulting rupture safety factors.

The corresponding allowable working stresses, S_H, in the "hot range" are shown by the steeply-sloping curves on the stress-temperature chart, Fig. 10. The allowable working stresses, S_L, in the "cold range" are taken as 0·21 of the ultimate tensile stress,* and are represented by the curves of moderate slope on the chart. As indicated earlier, the factor k in the wall thickness formula, equation (2) should be taken as 1·0 for the hot range, and 0·4 in the cold range, and the transition from one set of curves to the other should be made at the temperature at which both give the same wall thickness, i.e., at the temperature at which

$$S_L - S_H = 0{\cdot}6\ P. \quad . \quad . \quad (9)$$

For design purposes, the allowable working stresses would generally be given in tabular form as indicated on Table IV. The foot notes to that table explain how the change over from the cold to the hot design range is obtained. For live steam piping in modern power stations, the hot design range would almost invariably apply.

In the author's opinion, the above method of performing the change from the cold to the hot design condition is preferable to that adopted by the A.S.M.E. code, which introduces a "transition zone" with varying k. The same transition zone is adopted for all ferritic steels, though, in fact, true transition to creep behaviour commences much earlier in low-grade ferritic steels such as carbon steel, than in high-grade ferritic steels, such as molybdenum-vanadium.

The last items in Table III compare the minimum wall thicknesses calculated for standard steam conditions by the methods described above with the minimum thicknesses derived from B.S. 806 and the A.S.M.E. code. It will be seen that the proposals made in this article are intermediate between those of the British and American codes, except in the case of 0·5 per cent. Mo steel where attention to creep ductility has resulted in lower recommended wall thicknesses than those obtained by the established codes, and in the case of 2·25 per cent. Cr-0·5 per cent. Mo steel, where the weight lent to creep-rate data in the A.S.M.E. code appears to have produced relatively conservative thicknesses. The actual wall thickness would generally exceed the minimum thickness by manufacturing tolerances.

WELDING

Sound welds can be made for each of the steels described in this article, though highly-trained welders have to be employed, particularly with the austenitic steels, and with the higher-grade ferritic steels where electrodes of the "low-hydrogen" type are desirable. In some cases long-term tests on the weld metal have to be awaited before it can be stated with confidence that the weld metal has a strength comparable with that of the parent metal. In cases of doubt, it is desirable to employ slightly larger pipe wall thicknesses.

Creep test results on weld metal for two austenitic steels have been reported by E. Bishop and W. H. Bailey (1950).

* Actually design in the cold range should allow for the largest pressure which can occur. For operation in accordance with B.S. 132, the largest pressure would be 120 per cent. of the mean pressure, so that the effective safety factor on the ultimate tensile stress would be $\frac{1}{(0{\cdot}21 \times 1{\cdot}2)} = 4$.

TABLE IV. SUGGESTED METHOD OF SPECIFYING ALLOWABLE WORKING STRESS

Steel	Allowable working stress in lb. per sq. in. at following temperatures, deg. F.									Θ_A	M
	800	850	900	950	1,000	1,050	1,100	1,150	Θ_A		
										deg. F.	
Carbon	8,400	7,000	5,700	—	—	—	—	—	—	—	—
0·5 per cent. Mo ..	*13,800*	*12,100*	9,300	6,000	—	—	—	—	13,600	825	0·012
1 per cent. Cr—0·5 per cent. Mo	14,400	*14,000*	*11,800*	7,600	4,600	—	—	—	13,800	880	0·007
2·25 per cent. Cr—1 per cent. Mo	14,600	*14,200*	*12,700*	9,600	7,100	5,300	3,700	2,200	14,000	880	0·010
0·5 per cent. Mo—0·25 per cent. V	14,500	14,100	*13,800*	*12,000*	9,000	6,800	4,600	2,900	13,500	930	0·010
18 per cent. Cr—13 per cent. Ni—1 per cent. Nb	15,000	14,700	14,400	14,000	*13,500*	10,500	8,100	6,000	13,500	1,000	0·011

The Table shows the allowable working stress, S, to be used in determining the minimum wall thickness, t_m, from equation 2, using $k = 0{\cdot}4$ and $k = 1{\cdot}0$ below and above the transition temperature, Θ_t respectively, where $\Theta_t = \Theta_A + PM$, and Θ_A and M are given by the last two columns of the table.

For temperatures intermediate between those shown in the table linear interpolation may be used. The values of the stress at Θ_A should be used for interpolations between the temperatures shown in italic type.

CONCLUSIONS

In order to pass on to industry the results of new technical advances, or the benefit of increased confidence inspired by the release of additional test data, committees of specialists should publish their latest findings at frequent, say six-monthly, intervals. To preserve consistency and reduce the time and labour involved, the committees should use a definite framework in arriving at their recommendations. From the discussion in this article it appears that the framework should comprise the following points:

1. The allowable working stress of pipe steels for high temperature service should be derived from the long-term rupture strength of the steel, and a nominal "rupture safety factor."
2. The rupture safety factor should be chosen so as to give an approximately constant degree of security against failure. This requires that it should take account of various secondary properties of the steels, and secondary aspects of the service conditions.
3. Among these secondary factors are:
   (i) The creep ductility of the steel which becomes important when surface irregularities, non-metallic inclusions, weld stresses, etc., create initial stress concentrations in the material;
   (ii) The effect of pressure and temperature peaks of short duration;
   (iii) The tolerance on rupture stresses extrapolated to the service life from relatively short term test data;
   (iv) The variability of the quality of steels of a given nominal composition.
4. The allowances for the secondary factors should be summed in a systematic manner, taking account of the fact that some of the occurrences are "random" whereas others have a definite favourable or unfavourable bias.
5. The wall thickness of pipes should be determined from equation (2), which is the formula contained in the 1952 A.S.M.E. code, but the factor k may be taken as 1·0 at high temperatures. This gives the "inside diameter" type of formula. The "outside diameter" formula now used in B.S. 806 is particularly unsuitable for high temperatures.
6. In applying the wall thickness formula, the mean service pressure and mean service temperature may be used, provided the deviations in pressure and temperature do not exceed the amounts specified in B.S. 132. If they do exceed the amounts specified, then a larger allowance must be included in the rupture safety factor (point 3 (ii) above).
7. Corrosion allowances should not be constant, but should vary with the type of steel and the temperature. With the low-chromium content steels, corrosion becomes appreciable at temperatures above 1,050 deg. F.

The test data examined suggest that the high temperature strength of the three main pipe steels introduced in Britain for temperatures above 1,000 deg. F. increases in the order: 2·25 per cent. chromium-0·5 per cent. molybdenum; molybdenum-vanadium; 18 per cent. Cr-13 per cent. Ni-1 per cent. Nb steel.

ACKNOWLEDGMENTS

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APPENDIX I

LONG-TERM RUPTURE OF PIPE UNDER INTERNAL PRESSURE

Experimental evidence* indicates that the time T required to reach a creep strain x, along one of the principal axes is related to the work done in creep W, by a relation of the form:—

$$T = A\left(\frac{W}{x}\right)^{-n} x^m, \quad . \quad . \quad (10)$$

where the factor A is regarded as a constant for small ranges of variation of W and x. For a given material and temperature, its values depend on the ratios of the strains along the principal axes.

For pipe design two strain systems are important. The first (for which A will be denoted by A_1) is met in testing materials. It is the result of applying a pure tensile stress, $S = \frac{W}{x}$, to a specimen and the resulting strains along the principal axes, X, Y and Z, bear the relation:—

$$x = -2y = -2z. \quad . \quad (11)$$

For the rupture condition, T. S, and x will be denoted by T_r, S_r, and x_r respectively.

The second case (A is denoted by A_2) is the strain system which results when a pipe is exposed to an internal fluid pressure. Experiments by R. W. Bailey (1930) have shown that the longitudinal strain, y, is then zero, so that for constant specific volume:

$$x = -z. \quad . \quad . \quad (12)$$

It will be understood that the second strain system could be obtained by applying a tensile stress $\left(\frac{W}{x}\right)$ to an element of material prevented from deforming in the direction Y. This restriction on the deformation acts as a "brake" tending to reduce the rate of creep along X, and in consequence, A_2, would be expected to be larger than A_1. From certain hypotheses on the fundamental mechanism of creep R. W. Bailey (1935 and 1951) and others have shown how the ratio $\frac{A_2}{A_1}$ can be calculated, but the experimental evidence available at present is not sufficient to support accurate predictions of this ratio for the high temperature steels.

Since $y = o$, the work done per unit volume of material of a pipe bore, d, wall thickness, t, under internal pressure, p, is $W = \left(\frac{P d^2}{2 t x_b (d+t)}\right)$ where x_b is the strain at the pipe bore. The mean strain of the material is $x = \left(\frac{x_b}{1+\frac{t}{d}}\right)$ so that $\left(\frac{W}{x}\right) = \frac{P d}{2 t}$. Fracture occurs after time T_r when $x_b = x_r$.

Substituting the values discussed above in (10) one obtains for the rupture condition:—

$$A_1 S_r^{-n} x_r^m = T_r = A_2\left(\frac{P d}{2 t}\right)^{-n} x_r^m \left(1+\frac{t}{d}\right)^{-m}, \quad . \quad . \quad . \quad (13)$$

or rearranging and putting $\frac{m}{n} = f$ and $\left(\frac{A_1}{A_2}\right)^{\frac{1}{n}} = R$,

$$2 t S_r = R\left(\frac{P d}{2 t}\right)\left(1+\frac{t}{d}\right)^f. \quad (14)$$

When $\frac{f t}{d}$ is small, this approximates to:—

$$S_r = \frac{R P (d+ft)}{2 t}. \quad . \quad (15)$$

This may be re-written in terms of the outside diameter, D, and the factor $k = \left(1-\frac{f}{2}\right) = \left(1-\frac{m}{2n}\right)$. When this is done, equation (1) in the text is obtained.

APPENDIX II

ALLOWANCE FOR STRESS CONCENTRATIONS

Consider a material having an average stress level, S_a, and a high local stress, S_q, caused by a surface deformation, inclusion, or weld stress at a point Q. Suppose that the initial value of S_q is $(1+r)\,S_a$ where r may be termed the "stress raising factor."

As creep proceeds, the relatively rapid deformation of the material at Q causes a transfer of stress from point Q to neighbouring understressed parts of the material. As a result the local stress, S_q, becomes smaller and eventually tends towards the average stress level, S_a. It may, therefore, be expected to obey a relation of the type:

$$S_q = (1+re^{-cx})\,S_a, \quad . \quad (16)$$

where x is the strain at Q, c and r are factors which depend on the nature of the irregularity, and e is the base of Naperian logarithms.

The problem now is to find the constant stress, $(1+a_1)\,S_a$ which produces fracture in exactly the same time as the varying stress, S_q. For the purpose of this discussion it will be assumed that creep recovery is negligible, i.e., that the creep rate $\frac{dx}{dT}$ is uniquely determined by the instantaneous stress, S_q, and the strain, x. It will be represented by the customary expression:

$$\frac{dx}{dT} = K S_q^n x^{-p}, \quad . \quad . \quad (17)$$

where p is an index which is positive for low values of strain and then becomes negative as x increases.

To obtain the total time for fracture, one may integrate the inverse of the creep rate, i.e.:

$$T_r = \int_0^{x_r} \frac{x^p}{K S_q^n}\,dx = \frac{1}{S_a^n}\int_0^{x_r} \frac{x^p}{K(1+re^{-cx})^n}\,dx, \quad . \quad . \quad . \quad (18)$$

and this must also equal:

$$T_r = \frac{1}{(1+a_2)^n S_a^n}\int_0^{x_r} \frac{x^p}{K}\,dx. \quad (19)$$

Equating, one obtains:

$$(1+a_2) = \left\{\frac{\int_0^{x_r} \frac{x_p}{K}\,dx}{\int_0^{x_r} \frac{x^p}{K(1+re^{-cx})^n}\,dx}\right\}^{\frac{1}{n}}. \quad (20)$$

Since the index p and the factor K in this expression change with increasing x, the integration has to be performed graphically. It is sufficiently accurate for practical purposes to assume that the creep curve can be split into three distinct zones, each with a given value of p, namely, a positive value, p_1, in the primary zone, zero in the secondary zone, and a negative value, p_3 in the tertiary zone. The creep rates for the three zones are then represented by:

Primary zone:
$$\frac{dx}{dT} = K_1 S_q^n x^{-p_1} = K_2 S_q^n \left(\frac{x}{x_{12}}\right)^{-p_1}$$
Seondary zone:
$$\frac{dx}{dT} = K_2 S_q^n$$
Tertiary zone:
$$\frac{dx}{dT} = K_3 S_q^n x^{-p_3} = K_2 S_q^n \left(\frac{x}{x_{23}}\right)^{-p_3}$$
, (21)

where x_{12} and x_{23} denote the initial and final strains of the secondary creep zone.

The full curve in Fig. 9, shows the values of a_2 calculated for the following constants: $p_1 = 2$, $p_3 = -0{\cdot}8$, $x_{12} = 0{\cdot}02$, $x_{23} = 0{\cdot}06$ (these values being in good agreement with a number of experimental creep curves); $n = 5$ (which is a typical gradient of log time – log stress curves), and $r = 1{\cdot}0$, $c = 150$. The values of r and c are assumptions only, and no data are available to check these at present. Curve 2 on the figure is a linear approximation to Curve 1.

* Experiments by A. E. Johnson (1951) have shown that the addition of a hydrostatic stress does not modify creep behaviour. Hence for given ratios of the creep strains, the creep depends only on the total work done and not the individual values of the principal stresses.

* * *

GLASS FOR BUILDINGS

Mechanical Properties

In a paper entitled "The Engineering Aspects of Glass," presented to the Manchester Association of Engineers on March 26, Dr. R. E. Bastick and Mr. H. Cooper described the methods of manufacture and some of the building applications of glass. The properties which made it useful in this trade were its hardness, mechanical strength and durability, together with its thermal, optical and acoustic attributes.

Comparing the heat insulation of an 8-in. brick wall and a $\frac{1}{8}$-in. pane of glass, the authors took figures of 6 and 8 B.Th.U. per square foot per hour per degree F. per inch as coefficients for the two materials. These gave heat transfers of 0·42 and 1·1 B.Th.U. per square foot per hour per degree F. for the wall and the glass, respectively. They said that the best way to reduce the loss through the glass was to use double glazing, but it had been found that there was little to gain by having the two panes more than 0·75 in. apart, and at this spacing the heat transfer was reduced to 0·54 B.Th.U. per square foot per hour per degree F., or about half that of a single pane.

When glass was used for roofing, the authors said that the rupture stress for plate glass was usually taken as 2,670 lb. per square inch and for sheet, 5,350 lb. per square inch. It had been shown that the square pane was the strongest and that a simple method of calculating the safe glazing size was that the diagonal of a sheet of plate glass should not exceed 331 times its thickness; the figure for sheet glass was 469. The main use of wire in roofing glass was to prevent fragments falling after a fracture; it did not add any strength.

THE HOT EXTRUSION OF STEEL*

GLASS AS A LUBRICANT

By J. Sejournet, ING.E.P., M.SOC.C.E.(FRANCE)†

The production of bars, shapes and tubes of steel by hot extrusion has been under consideration in most industrial countries for many years. In France, experiments carried out in 1925 by the Aciéries Electriques d'Ugine indicated that steel could be extruded under suitable conditions, but the rapid wear of the dies prevented commercial adoption of the method at that time.

In 1938, the Ugine Research Laboratories, which were working on heat-resisting steels and alloys, thought that they had found the composition of a new heat-resisting alloy that could be used for the making of extrusion dies. At that time, the Comptoir Industriel d'Etirage et Profilage de Metaux, a private company engaged principally in the cold drawing of metals, was extruding non-ferrous metals and alloys in a small press in Paris. Ugine and Comptoir d'Etirage signed a technical agreement to co-ordinate their researches on the extrusion of steel.

After studying the problem from the scientific point of view, the conclusion was arrived at that the first problem to be solved was lubrication, and that the lubricant which would have the necessary qualities should have a viscous phase, intermediate between the solid and the liquid state, at the operating temperature. To ensure adequate lubrication the material must be applied solid and become viscous, but not liquid, when in contact with the hot billet. Under such conditions the coating that covers the billet offers resistance to deformation and is able to sustain the pressures occurring; hence it is extruded continuously with the bar. This method, moreover, has the advantage of using materials which, being excellent heat insulators, protect the tools from over-heating. Glass or glass-like materials of various compositions seemed likely to meet the required conditions and in point of fact they led to the general solution of the problem of the extrusion of steel.

An extrusion press specially designed for steel extrusion was installed in a new plant at Persan, near Paris. The new installation was started up late in 1949 and it is now clear that the extrusion of steel is a commercial process that will find increasing applications. The raw material used is in the form of round ingots, in the as-cast or turned condition, or in the form of rolled or forged bars. The smallest diameters of the ingots or billets are about 3 in. for a 300-ton press and 16 in. for a 4,000-ton press. The length of the ingots ranges from 8 in. to 32 in., depending on the reduction of area required and the capacity of the press.

THE PROCESS

The billet is preheated in a furnace to the requisite temperature: it is then introduced into a hollow cylinder or container made of heat-resisting steel. The container is closed at one end by a die, the opening of which represents the outline of the section of the bar to be extruded. High pressure, of a value ranging between 35 tons and 71 tons per square inch, is applied at the other end of the container by means of a ram, as a result of which the metal is extruded through the die aperture. At the end of the operation a short length of ingot, called the discard, remains in the container and is ejected after having been cut from the bar by a saw. For the extrusion of tubes the bar is pierced prior to extrusion; a mandrel is set at the centre of the extrusion die and the metal is thus forced to flow over the mandrel when passing through the die.

The process has many advantages, among which is quick and easy tool changing, permitting extrusion of small quantities of different sections without incurring extra expense. Also, the tools are cheap. In some cases it is possible to make, in a few hours, dies weighing about 2 lb. from a 9 per cent. tungsten, 3 per cent. chromium steel. The installation of a press costs less than that of a rolling mill; the output of the press, though lower than that of a rolling mill, can nevertheless reach high tonnages. In an installation in good working condition the losses of metal are confined to the discards, the thickness of which can be so reduced as to give a yield of 95 per cent.

GLASS LUBRICANT

Turning now to some special features of the technique used in the process and dealing first with the glass lubricant. The surface of the glass that is against the hot billet is heated, causing the material to pass from the solid to the viscous phase. Lubrication is continuous and the extruded bar emerges from the die wrapped in a coating of glass the thickness of which is about 0·0001 in. Extrusion without lubrication is conducted with a friction coefficient between the container and the billet of about 0·12. With ordinary glass lubricant this falls to 0·04, and with special glass it may fall to so low a value that it is no longer possible to notice any difference between the pressure at the beginning and the pressure at the end of the operation.

When extrusion is performed on steel with glass lubrication, the whole billet goes forward virtually undeformed and the deformation only starts at the very last moment, the surface of the billet becoming, by elongation, the surface of the bar. When, on the other hand, a billet of aluminium alloy is extruded without lubricant, the middle portion of the billet flows more quickly than the outside and the portion in contact with the die has a tendency to stay on the die, resulting in a build-up of metal. In this case the surface of the extruded bar is generally formed of metal coming from the inside portion of the billet.

HOMOGENEOUS STRUCTURE

This leads to the conclusion that the bars extruded with a suitable lubricant have homogeneous structures, their mechanical properties being constant all along the bar, while, in the case of non-lubricated extrusion this structure varies from one end of the bar to the other. It is clear that, even in the case of metals usually extruded without lubricant, it would be desirable to adopt lubrication in order to give to the extruded product a homogeneous structure.

As the surface of the billet becomes the surface of the extruded product in the case of glass-lubricated extrusion, it has been easy to improve the surface condition of the products. The design of die-holders and dies being such that the metal is deformed in the manner I have just described, it was concluded that the surface defects found on the extruded product were due to defects on the billet. The consequences of the various surface defects of the billets were therefore studied and the surface conditions of the extruded products were improved by eliminating from the billets such defects as are particularly detrimental.

SCALE AVOIDED

The heating of the billets is now one of the most important questions in connection with the extrusion of steel. It was realised very quickly that the scale covering the billet during heating had to be eliminated, since the billet is enclosed in a container from which the scale cannot get out except by adhering to the surface of the extruded bars, causing scratches on the dies and defects on the extruded products.

It was therefore necessary to use heating methods which would either avoid the formation of scale or transform the scale into a viscous substance which would not scratch the dies. From the very beginning a system was adopted of pre-heating the billets up to 850 deg. C. in a conventional gas furnace, followed by a final heating in a bath of barium chloride. The chemical and physical influence of the salt rendered it possible to extrude without any detrimental effect caused by oxides. This method ensured safe heating and permitted further developments in the extrusion process. Unfortunately it has the drawback of being expensive, thus limiting certain applications, particularly as regards the extrusion of ordinary steels.

Several solutions are now under consideration and I propose simply to mention them although it is still too soon to indicate which will eventually be adopted. For ordinary carbon steels it seems that the most economical solution consists in heating the billets in a conventional gas or fuel-oil furnace and removing the scale quickly by means of high-pressure water sprays after heating. For stainless and special steels, low-frequency heating furnaces have been adopted by American firms which are just commencing to extrude steel. The cost of this method is perhaps slightly higher than that of ordinary means of heating, but is still cheaper than heating in salt baths. Another alternative is to employ gas furnaces of special design which heat the billets with practically no formation of scale. These furnaces have been tried in Great Britain.

A note on this paper appears in Weekly Survey in this issue.

* Paper entitled "The Ugine-Sejournet Process for the Hot Extrusion of Steel," presented at a joint meeting of the Iron and Steel Institute and the British Section, Société des Ingénieurs Civils de France, held on Thursday, April 1, 1954. Abridged.

† Directeur Général, Comptoir Industriel d'Etirage et de Profilage de Métaux.

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PLASTIC CONDUIT

For Corrosive Conditions

The General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2, have produced a conduit tube made in polyvinyl chloride which can be used for electrical installations, or parts of installations, where severe corrosive conditions exist. It is resistant to the majority of acids, is unaffected by moisture or damp, oil or grease, and may be buried in the ground, lime, mortar or cement. Lighter than steel or aluminium, it is non-inflammable, does not split or fracture, and remains rigid in temperatures up to 140 deg. F.

The constituents of the tube are so balanced as to enable it to be manipulated and fitted like steel conduit. A separate earth wire must be run to ensure satisfactory continuity.

The standard G.E.C. range of malleable-iron or pressed-steel conduit fittings can be used with this tube but first need either coating with polyvinyl chloride or painting with a chlorinated rubber. This can also be used for touching-up and sealing joints on the final installation. The polyvinyl chloride tubing conforms to the Institution of Electrical Engineers' wiring regulations.

ELECTRIC POWER LINK BETWEEN BRITAIN AND FRANCE*

MUTUAL HELP AT PEAK LOADS

By D. P. Sayers, B.SC., *M. E. Laborde*, ING.E.S.E., *and F. J. Lane*, O.B.E., M.SC.†

Since 1950, the technical problems involved in establishing a link between the British and French electricity supply systems have been under investigation by a Joint Committee of representatives of the British Electricity Authority and Électricité de France. Proposals for a cross-Channel tunnel have been made at various times since 1800, the last occasion being in 1929 when a Committee reported favourably on the engineering and geological conditions. The Government, however, decided that the economics of the scheme had not been adequately established, reiterated the strategic objections and decided that the scheme should be dropped. In the light of this information the Joint Committee decided that any scheme for a power cable across the Channel which involved the construction of a tunnel was not immediately practical, and that further studies should be confined to the possibilities of a submarine cable laid direct in the sea.

SUBMARINE POWER CABLES

Many submarine power-cable installations exist, but most of them are comparatively short or are operated at voltages below about 60 kV. The longest undersea cables off the coasts of Britain are the 33-kV three-core cables between the mainland and the Isle of Wight. A three-core cable, about 3·4 miles long and designed for 132 kV was laid between Sweden and Denmark in 1951 and another recent installation is the 60-mile cable laid during 1953 between Sweden and the Island of Gotland and designed for direct-current operation at 100 kV. An important installation in course of construction is the 69 kV circuit across the St. Lawrence River (32 miles) in Canada. Connections between Vancouver Island and the mainland of British Columbia, between the North and South Islands of New Zealand, and between Australia and Tasmania have also been suggested.

Submarine cables may be subjected to relatively severe mechanical stresses during laying and are exposed to hazards after installation which do not arise with buried land cables. These include corrosion by salt water, abrasion against rocks, movement due to sand erosion and direct damage by ships' anchors and fishing gear. Existing records do not lead to any reliable assessment of the fault incidence to be expected on a high-voltage cable across the English Channel, although they emphasise that a fairly serious element of risk must be accepted. The development of techniques for quick repairs and the availability of ships and repair material are therefore integral parts of the main problem. Furthermore, allowance for the effect of faults on the operational availability of the circuit must be taken into account.

BRITISH AND FRENCH SUPPLY SYSTEMS

On the British Electricity Authority's system, 99 per cent. of the energy is produced by thermal stations, whereas in France, in 1952, 55 per cent. was generated in hydro-electric stations; and if the year had been one of average rainfall, with the existing installations, this proportion would have reached 62 per cent. There are thus significant differences in the availability and costs of generation at different times. As shown in Fig. 1 the variation between summer and winter maximum demands is much smaller in France than in Britain, while the annual load factor is 61 per cent. as against 44·9 per cent. in this country. The maximum demands in the two countries also occur at different times, owing to differences in climate, habits, national standard clock times, hours of work, industrial, commercial and domestic uses of electricity and weather variations. With adequate interconnection the total generating capacity required in the two countries to meet their combined simultaneous maximum demand can be reduced.

The existing transmission systems on the two sides of the Channel both operate at 50 cycles. The British 132-kV grid extends as far east as Folkestone and the nearest station on the 275-kV system will be near Northfleet, some 60 miles north-west of Dover. On the French side the 225-kV system terminates at Holque, some 19 miles inland from Calais. The French 90-kV system is connected to Calais, Boulogne, Dunkerque and Holque. There are thus four system voltages to be considered and whatever operating voltage is selected for the connection, transformers will be required at one end or the other. The selection of cable transmission capacity is determined by the maximum load which would be transmitted; the date at which service operation is required; the availability of capital; and the possibility of changing from alternating to direct-current transmission within the foreseeable future. These factors led to the preliminary conclusion that the initial capacity of interconnection should not be less than about 400 MVA at 275 kV and not less than 100 MVA at 132 kV. In both cases the length of the four single-core cables required would be 26 miles, with a conductor cross-section of 0·6 sq. in. at 275 kV and of 0·2 sq. in. at 132 kV. The total cost per kilowatt of capacity would be £29 at 275 kV and £43 at 132 kV. In addition to other factors, the charging current of the cable must be as low as possible to minimise voltage-rise effects and to limit the current rating. This charging current would be 316 amperes per phase at 275 kV and 180 amperes per phase at 132 kV. Shunt reactors are considered necessary for a 275-kV scheme to limit the effects of the charging current, but not on a 132-kV scheme.

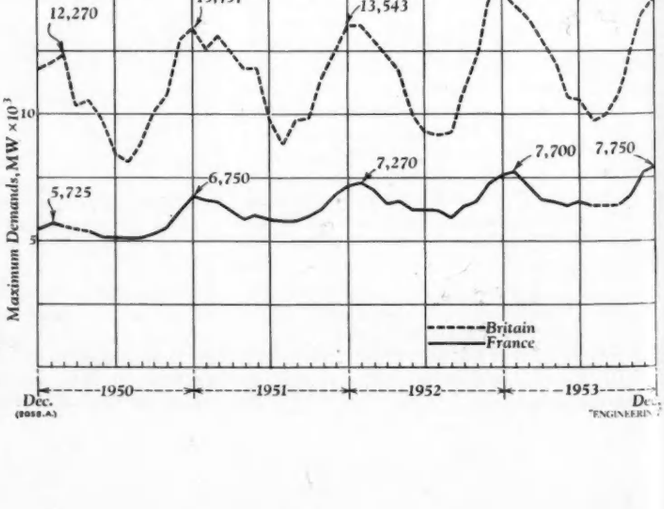


Fig. 1 Monthly maximum demands for electric power on the British and French systems during 1950-53.

DIRECT-CURRENT POSSIBILITIES

If the problem of conversion of alternating-current power to high-voltage direct-current power can be solved technically and economically the use of direct-current for the cross-Channel connection would have two important advantages. It would enable the effective power transmitted per cable to be increased 2½ times and would allow the exchange of power between two alternating-current systems operating at different frequencies. On the other hand, the magnetic field set up by a 200-kV single-core cable laid at a depth of 25 fathoms across the Straits of Dover and transmitting 100 MW would cause the compass of a ship immediately above it to be deflected about 4 deg. If, moreover, an uninsulated sheath return were used with a single-core cable the sea would carry almost all the current. As there must be some voltage drop, one end would become positive relative to the other and this positive end would suffer serious electrolytic corrosion. A possible remedy would be to make the cable sheath cathodic by circulating current between it and the positive pole of a separate direct-current supply. Considerable difficulties might arise, however, particularly in relation to other cables and metallic substances in the neighbourhood.

It is therefore evident that corrosion risk exists if direct-current is carried by single-core cables with uninsulated sheaths. Adequately insulated sheaths appear to be impracticable and the alternative of using a cable with two insulated cores would make design more difficult and increase the cost. The Joint Committee therefore decided that a direct-current interconnection scheme was not immediately practicable, but the possibility of a large-scale direct-current experimental transmission using a spare single-core cable merited serious consideration.

CABLE DESIGN INVESTIGATIONS

As a result of the studies made, the Joint Committee reported in May, 1952, that there did not appear to be any insuperable difficulties in the installation of a cross-Channel link and that the connection would be economically worthwhile. As so little was known about the hazards associated with the proposed submarine cable they also recommended a period of development covering the production, testing and installation

* Paper on "The Possibilities of a Cross-Channel Power Link Between the British and French Supply Systems," read before the Institution of Electrical Engineers on Thursday, April 1. Abridged.

† Mr. Sayers is with the Midlands Electricity Board, Mr. Laborde is with Électricité de France, and Mr. Lane with the British Electricity Authority.

of sample lengths of cables and joints, methods of surveying the route and of laying the cable as well as the location of faults and repair technique. This development, they considered, should be confined to 132 kV, owing to the greater cost of a 275-kV scheme and the relatively smaller financial benefits.

CHANNEL CONDITIONS

The surrounding medium for cables laid in the Channel is chemically active sea water varying in depth up to 216 ft., moving to and fro with the tidal conditions and subject at its surface to the vagaries of the weather over a wide area. At the narrowest point – to which cost would restrict installation – steep cliffs are general and there are rocky foreshores at possible access points on the English side. On the French side, east of Cap Gris Nez, a wide sandy foreshore, shallow and exposed at low tide for a distance of some 2 miles, presents serious approach difficulties. The bed of the Channel is mainly sand and shale with occasional rocky outcrops, with one particularly large sandbank – the Varne – in mid-Channel rising to within 10 ft. of the surface at low water. Wrecks would add to the hazards during laying and service and anchors dropped and dragged would also be threats. Finally, communication cables already occupy some of the route and would have to be crossed by the power cable.

Consideration of the above factors and of the difficulties likely to be encountered during laying suggested that the number of joints to be made at sea during laying should be kept to a minimum, that a flexible joint must be available for works use and be no weaker and no more difficult to handle and lay than the main cable; and that a rigid joint, which must be suitable for rapid completion on a ship, would be necessary for repairs at sea. In addition, the armouring must give maximum protection against mechanical damage, consistent with manœuvrability during manufacture and laying; and must have a high resistance to chemical attack and abrasion. Local damage to the outer sheath and reinforcement should not result in excessive contamination of the insulation. Special additional armouring to limit damage from rocks and anchors might be necessary, while the terminal lengths would require special consideration, owing to the effect on the current rating of the change from sea water to earth as a surrounding medium. If single-core cables were employed they would have to be laid 1,000 yards apart to provide adequate clearance for grappling. Accurate fault location would be very important.

BRITISH DEVELOPMENT PROGRAMME

Five types of cable, of which full details are given in the paper, were considered; and it was finally agreed that works development tests and laboratory and sea trials should proceed on 132-kV gas-filled pre-impregnated and gas compression cables, single-core cables being preferable to three-core cables because the dimensions are smaller and the joints simpler. The British engineers considered that the gas-filled pre-impregnated cable would be more suitable in view of the simplicity of the gas-pressure system and the possibility of manufacturing it in long continuous lengths. A basic specification for such a cable was agreed with manufacturers having experience with extra-high-voltage cables in which, inter alia, it was laid down that a copper cross section of 0·5 sq. in. should be selected, although 0·2 sq. in. would have been adequate to carry a load of 100 MW. This increased section provided a reasonable margin of mechanical strength, reduced the effective transmission losses and permitted greater freedom

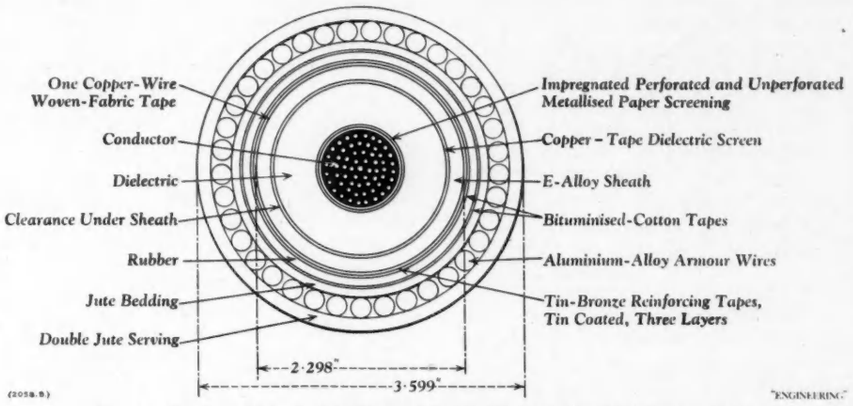


Fig. 2 Cross-section of 132-kV gas-filled cable used for British sea trials.

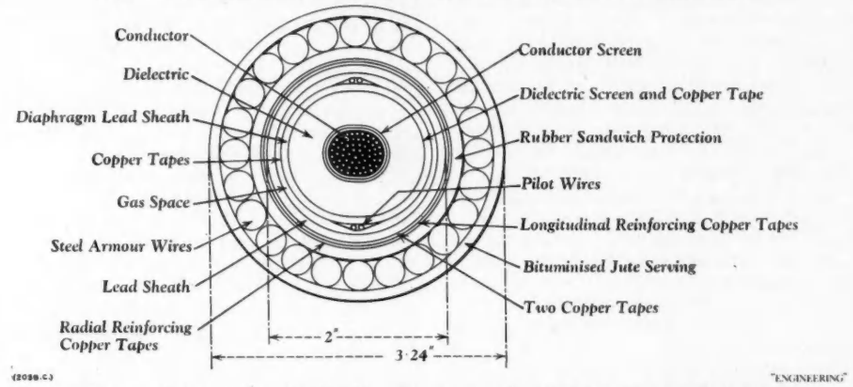


Fig. 3 Cross-section of 132-kV compression cable used for French sea trials.

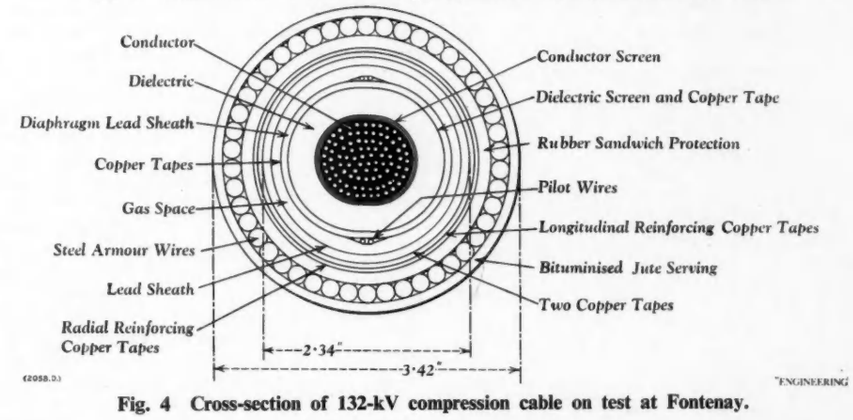


Fig. 4 Cross-section of 132-kV compression cable on test at Fontenay.

for transfers above 100 MW. The radial thickness of the paper insulation was determined at 0·5 in. on the basis of a maximum stress at the conductor of 90 kV per centimetre and a screen stress of 41 kV per centimetre. This latter value is important, since the insulation under the copper-tape dielectric screen would be subjected to the most severe mechanical handling and to the local heating associated with the sheathing process.

The mechanical handling forces and the indeterminate stresses likely to be imposed on the cable indicated that the lead sheath should be proof against vibration. It was therefore agreed that an alloy containing 0·4 per cent. tin and 0·2 per cent. antimony should be employed. The fatigue limit of this alloy is 0·42 tons per square inch compared with 0·18 tons per square inch for pure lead. The wall thickness of the lead sheath was fixed at a minimum of 0·14 in. partly to give mechanical security during handling, but principally to ensure that if the cable were laid without internal pressure the sheath would not collapse under the external pressure of 100 lb. per square inch which might be experienced at the deepest part of the Channel.

A diametric clearance of some 40 to 50 mils was to be provided under the lead sheath to give a gas space area of about 0·16 sq. in., in order to accelerate gas charging and assist gas-leak location. The sheathand armour losses using galvanised-steel wire armour would amount to about 170 per cent. of the conductor loss. As the general mechanical and corrosion-resisting properties of certain aluminium-alloy wires were at least equal to those of galvanised steel, and since their use would reduce the losses to about 61 per cent. of the conductor loss, it was decided to employ this material, in spite of the increased risk of electrochemical corrosion between the aluminium alloy wires and the bronze reinforcing tapes if the intervening rubber layer were damaged. While investigations confirmed the suitability of aluminium-alloy armouring as a corrosion-resistant material, tests indicated that the abrasion when immersed in salt water was six times greater than with steel.

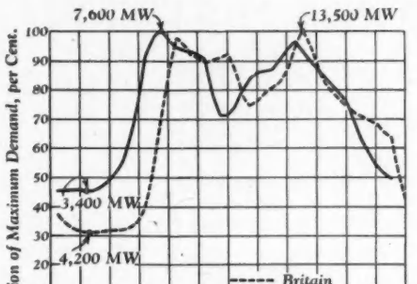


Fig. 5 Curves of percentage maximum demand, showing differences between British and French systems on a typical winter's day, December 10, 1952.

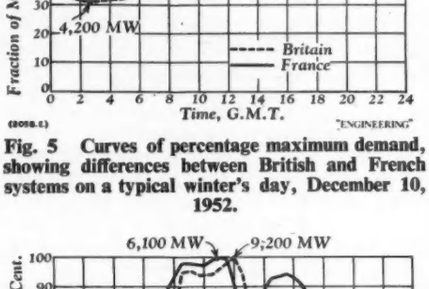


Fig. 6 Curves of percentage maximum demand, showing differences between British and French systems on a typical summer's day, June 18, 1952.

TESTS PRIOR TO SEA TRIALS

Prior to the sea trials it was not possible to give full attention to the rigid or "sea-going" joint and the joints developed at this stage were based on the conventional box pattern. In addition to normal type tests, special tests were made to determine the behaviour of the cable and joints when gas-filled at atmospheric pressure, but subjected to external pressure corresponding to deep laying. Power factor stability and impulse tests were made on flexible and rigid joints as well as bending tests on flexible joints, lowering tests on rigid joints and coiling down tests.

It was found possible to produce a flexible joint with the same external diameter as that of the main cable by butt brazing the individual strands and using a lead burning technique to joint the outer lead sleeve of the joint to the lead sheath of the cable. With such a joint it was found possible to achieve an impulse withstand level of about 550 kV, compared with the 640 kV normally specified for a 132-kV system.

SEA TRIALS UNDERTAKEN

The principal characteristics of the British cable selected for the sea trial and those of the French cables tested at the works, and at Fontenay are compared in the Table above, while Figs. 2 to 4 show the comparative cross-sections of the British pre-impregnated gas-filled cable and the French external compression cables.

The object of the sea trials, which were made between July 21 and September 9, 1953, was primarily to determine the effect on the cable and its joints of the severe mechanical conditions associated with laying from a cable ship and to obtain experience in the making and laying of joints at sea. Two lengths of British cable about 880 yards long were prepared, each with a factory-made flexible joint at the mid-point. The French manufacturer prepared a length of about 230 yards of similar cable, but without a flexible joint. Initially, the weather was favourable and arrangements for landing the terminal end proceeded without any serious difficulty, although minor problems arose from the drift of the tide and the presence of rocks close inshore. When the first rigid joint was being made, however, the weather became worse, so that further work was impossible. The cable was therefore cut, sealed off and buoyed, and the ship returned to harbour where the stop-end joint was completed on the French length of cable. This stop joint was then dropped in the sea and the French cable laid towards the shore to a position where it could be connected to the second British length. The seaward end of the first British cable was jointed to the second length, which was laid and jointed to the French length. The whole of this operation was completed without pressurising the cable. Subsequently, the cable was pressurised and subjected to high-voltage direct-current tests at 300 to 400 kV, after which both it and the joints were taken back to the works.

PRINCIPAL CHARACTERISTICS OF 132-kV CABLES FOR THE BRITISH SEA TRIAL AND THE FRENCH TESTS AT THE WORKS AND AT FONTENAY

Cable	Rating, MVA.	Conductor Area, sq. in.	Max. Stress, kV per cm.	Thickness of Insulation, in.	Armouring	Overall Diameter, in.	Weight, lb. per yard	Losses per 26-mile Three-phase Circuit at 100 MW. Conductor, kW.	Dielectric, kW.	Sheath, kW.	Total, kW.	Charging Current per phase, Amperes
British. Pre-impregnated gas-filled	200	0·5	90	0·515	0·232 in. aluminium alloy wires.	3·6	36	1,410	141	860	2,411	208
French. Pre-impregnated gas-filled	200	0·62	85	0·51	0·2 to 0·3 in. steel wires.	3·54	51	1,400	230	1,300	2,930	245
External compression ..	200	0·59	117·5	0·35		3·40	54	1,540	250	1,260	3,050	365
Pre-impregnated gas-filled	100	0·24	85	0·63		3·30	42	4,370	140	3,240	7,750	155
External compression ..	100	0·19	125	0·40		3·15	44	5,000	150	3,100	8,250	215

IMPORTANT LESSONS LEARNED

Among the important lessons learned from the sea trial and other experimental work was that the length and direction of the lay of the armouring, the size of the wire and the space factor have an important bearing on the way the cable coils into the tanks of the ship and on the possibility of kinking when it is manœuvred on deck for jointing. It was also found that if the rubber layer between the armouring wires and the reinforcing tapes was damaged, sea water might penetrate for appreciable distances, unless close and continuous contact were maintained between the rubber and the tapes. The mechanical strength of the reinforcing tapes must therefore be determined not only with regard to the pressure within the cable, but also to the severe treatment when handling. Rough handling of the cable near a flexible joint in the vicinity of a cut or free cable end will almost certainly cause longitudinal displacement between the conductor and the sheath with resultant damage to the hand-applied dielectric, unless the conductor, sheath and armour are mechanically anchored together at the free end. Joints to be made at sea must be simplified as much as possible, so as to minimise the time required for making. A construction limiting the amount of conductor movement relative to the sheath, as well as means for restricting the bending radius at the entrance to the joint will be necessitated by the severe handling during jointing and laying. Shore end conditions may necessitate the construction of a channel through the rocks and the provision of "rock armour" on the cable to minimise damage during laying and in service.

FRENCH DEVELOPMENT PROGRAMME

The cables tested under the French development programme were of the gas-filled pre-impregnated and the external gas compression types. The latter was included because of its higher working stress and consequent reduced insulation. Since this type of cable is not easily manufactured in long lengths it is particularly important to develop suitable flexible joints. The individual test lengths of both types were manufactured to the same basic specifications, although there were variations in detail. It was decided to test cables suitable for transmitting both 100 MW and 200 MVA, the object of including the latter being to investigate the influence of the increased diameter and weight on the manufacture and laying and on the reliability. The principal characteristics of the four cables are given in the Table.

As the British sea trials were to be made with pre-impregnated cables, it was decided that the French sea trials should be confined to external compression cables in order to avoid problems in

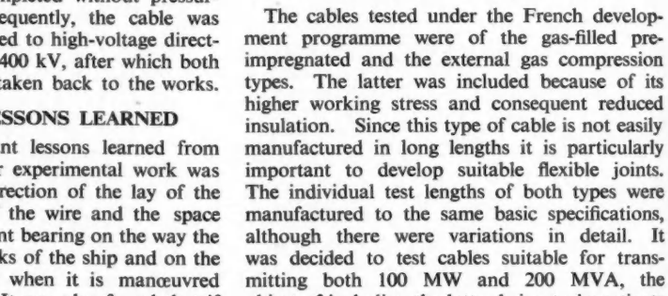


Fig. 7 Daily peak loads in Britain and France, plotted as percentage of winter maximum demand.

connection with joints and fault location. It was also decided to use two types of joint for each type of cable. One of these was of the flexible type, which could be manufactured in the works and would enable the complete cable to be laid in one operation. The other was a rigid joint suitable for repairs at sea.

The programme provided for individual works tests, comparative tests at the Fontenay Research Centre and sea trials. The first two applied equally to the two types of cable selected and the third only to the external gas-compression cable. The tests at the works were made on short samples to determine the insulation withstand level under 50-cycle impulse and under direct-current conditions; and to give some indication of the life curves of the cables and their accessories. They were also made to check the ability of the cables and joints to withstand the estimated mechanical stresses to which they might be subjected during manufacture, transport, laying and operation. The results showed that for the compression type of cable stresses of about 400 kV per centimetre could be obtained in the laboratory and that flexible joints could be designed for both types of cable with a dielectric safety factor practically equal to that of the cables themselves.

TESTS AT FONTENAY AND SEA TRIALS

The tests at Fontenay were designed primarily to supplement the works tests, using larger and more powerful testing plant, and to obtain directly comparable results by investigating the cables and joints under identical conditions.

The programme of French sea trials was in two stages. In the first the object was to obtain information on the behaviour of the compression cable and its accessories during laying and so to determine what modification to the specification of the test cable and laying plant might be needed. In the second, additional lengths of cable will be laid and jointed at sea in order to study the jointing and repair procedure, the location of the cable and faults and the rate of water penetration under fault conditions. The site chosen for these trials is at the end of the Carnot jetty at Boulogne-sur-Mer, where practically the whole of the comparatively short test cable will be submerged in fairly deep water.

One of the cables used for these trials is shown in Fig. 3, and they comply generally with the particulars given in the bottom line of the Table. Each of the four manufacturers participating in the test provided a length of about 120 yards, which were jointed with three flexible joints, and the whole length was then armoured in one operation. One end was terminated in a stop-end joint and the complete assembly was tested at 400 kV direct-current before being transported by rail to Boulogne and coiled down on the flat deck of a barge. On December 15, 1953, the barge was taken out to the pierhead and the cable laid out on a nearly straight course. After the end on the pier had been fitted with a 225-kV sealing end the installation was successfully tested at 400-kV direct current. In January, 1954, further high voltage tests and then low voltage heating cycles to check the thermal characteristics of the cable were made.

Two additional lengths of cable to the same specification, each about 540 yards long and including one flexible joint, will be jointed with a flexible joint and laid at sea as a continuation of the test length laid in December, 1953. This will involve making the closing joint at sea. After high voltage tests have been carried out, an artificial gas leak will be made in the cable by a diver and the accuracy of various methods of locating the fault will be investigated while the maintenance of pressure and the penetration of sea water are studied. Subsequently, it is intended to raise the cable at the faulty point and repair it at sea. After final high voltage tests up to 600 kV the cable and joints will be recovered and returned to the laboratory.

OPERATIONAL CONSIDERATIONS

If the full value of the interconnection is to be obtained the two systems must operate continuously in parallel. The capacity of the link is small in relation to the demands and accurate control will be essential. It is therefore necessary to be able to predict the fluctuations that are likely to occur in practice and the degree of control needed.

A series of large-scale tests has been carried out to assess the national power/frequency relationships for various conditions of power and load, and to correlate the fluctuations of power transfer between the two systems, when interconnected, with the fluctuations in the difference between their frequencies, when disconnected. These tests were broadly of three types. With the two halves of the system connected by a single line carrying a certain transfer the line was tripped and the power/frequency relationships for each of the two halves were calculated. With the system interconnected a substantial block of generating plant was switched out, thus enabling a direct assessment of the national power/frequency relationships to be made. With the same system arrangement as in the first test the two halves of the country were operated interconnected for about 15 minutes, each half trying to maintain the frequency at exactly 50 cycles and zero transfer on the interconnector. The interconnector was then opened and for a similar period each half of the country again tried to maintain this frequency.

The results of these tests indicated that in Britain a change in frequency of 0·1 cycle corresponds to over or under generation of 300 MW. In France, the corresponding figure is 100 MW. The French system is already provided with a measure of automatic frequency control which is being extended. The British system is not automatically controlled, but investigations are in progress to determine the effects of installing such equipment.

On the information at present available, the fine degree of control needed for the satisfactory operation of the proposed link could be obtained only by the use of automatic equipment. This problem is being further investigated by establishing a direct communication circuit between London and Paris and recording for a period the differences between the two frequencies.

ECONOMIC ASPECTS

The economies to be expected from interconnection consist of savings in capital investment on generating plant due to a reduction in the total amount required in the two countries by pooling spare plant and by diversity in maximum demand. There would also be savings in operating expenses due to the transfer of energy from one country to another when the costs of production were different. These savings have been assessed by detailed discussion between the operating staffs.

During the winter, diversity occurs between the demands on any given day largely because the French national time is then one hour in advance of Greenwich Mean Time. Moreover, in December, which is now the most critical month in Britain, the French daily maximum demand occurs at 8.30 a.m. (7.30 a.m. Greenwich Mean Time) while in Britain the daily maximum demand is at 5 p.m. Greenwich Mean Time. The diversity during a typical winter's day is illustrated in Fig. 5 which shows the half-hourly demands for France and Britain plotted on a percentage demand basis for easy comparison. The demand on a typical summer's day is shown in Fig. 6. Day-to-day diversity also occurs, mainly owing to differing weather conditions in the two countries and the fact that the biggest demand is on Wednesday in France and on Monday in Britain. In Fig. 7 the daily maximum demands for the two countries are plotted for the period November, 1952, to February, 1953, inclusive, again on a percentage basis. It will be seen that the British maximum demand occurred on December 15, 1952, and the French on January 9, 1953.

SAVINGS IN CAPITAL INVESTMENT

On the basis of experience over recent years the Joint Committee considered that a minimum winter diversity of 300 MW could be relied on. If a 100-MW interconnector were installed, each country could rely on receiving 100 MW from the other country at the time of its maximum demand, thus making possible a reduction in the plant capacity otherwise necessary. The combined saving (at 1951 price levels) was estimated at about £10 million, against which the capital cost of the connection was £4·3 million. For the 400-MW scheme the net saving was only £3·5 million, because no diversity greater than 300 MW could be assumed.

The three types of economic energy transfer that have been investigated are first the export of hydro-electric energy, which she is unable to absorb herself, from France to Britain to take the place of an equivalent amount of thermal generation in this country. The second is the export of surplus power from France to Britain during the daily peak period in this country, replacing generation by stations with the highest fuel costs per kilowatt-hour. Britain would return this energy during off-peak periods on the same day, thus correspondingly reducing the production of the French reservoir stations. Finally, when the cable was not fully utilised by these two exchanges the costs of production of thermal energy in the two countries would be compared and economic exchanges made.

It would not be possible to operate under all three of these conditions at the same time, but on the assumption of an optimum combination throughout the year the annual savings to be shared between the two authorities have been estimated as £100,000 under the first condition, £150,000 under the second and £350,000 under the third making a total of £600,000. The full realisation of these savings would depend on ideal operation of the interconnection, assuming no monetary exchange difficulties and a rate of exchange of 980 francs to the pound. In practice the actual savings would be rather less than these figures.

OVERALL ASSESSMENT

The realisation of these savings would depend on the cable being available for service at all times. There is little doubt that suitable cables can be manufactured and installed. The only doubt is the risk of breakdown after installation and the practicability of effecting quick and satisfactory repairs. The provision of a fourth single-core cable as a spare, with facilities for switching it in place of one of the cables normally in use, would clearly ensure a higher availability of the circuit. Doubt also exists as to whether the two systems can operate continuously in parallel through an interconnection of the size under consideration. The prudent course would appear to be an initial installation of the minimum capacity consistent with reliable operation but planned with a view to increasing the capacity when service experience has proved its worth.

THE BRITISH FIVE-TON DEADWEIGHT STANDARD OF LOAD*

INSTALLED AT THE NATIONAL PHYSICAL LABORATORY

By H. V. Pollard, M.B.E., M.I.MECH.E., *and R. G. Hitchcock*

For some years there has been at the National Physical Laboratory, Teddington, a British 50-ton deadweight standard of load.† This equipment has been used to calibrate various types of secondary standard instruments such as proving rings, weigh-bars, etc., which, in turn, are used to calibrate the load-measuring indicators of testing machines. The normal minimum load of the 50-ton standard is two tons, and in order to meet the need for accurate calibration of secondary standard instruments in the lower ranges of load, a five-ton deadweight primary standard of load has been designed and constructed in the Engineering Division of the Laboratory and is now installed in the Metrology Division. The arrangement is such that deadweight loads in progressive increments of 200 lb. from 400 to 11,200 lb. can be applied to any instrument which can be accommodated in the machine, the limiting dimensions being 4 ft. high by 1 ft. 11 in. wide.

For the purpose of this standard of load the unit of force employed is the gravitational pull on a one-pound mass (*in vacuo*) acted upon by Standard Gravity, 32·1741 ft. per second per second. Since the standard is to be used at the National Physical Laboratory where $g = 32{\cdot}1911$ ft. per second per second, allowance has been made for the difference between local and International Standard Gravity by adjusting the masses of the scale-pan assembly and the 108 weights which serve for the application of the load. Allowance has also been made for atmospheric buoyancy.

* Communication from the National Physical Laboratory.

† "The British 50-ton Deadweight Standard of Load installed at the National Physical Laboratory, Teddington." Phillips, C. E., *Proc., Seventh International Congress of Applied Mechanics*, 1948.

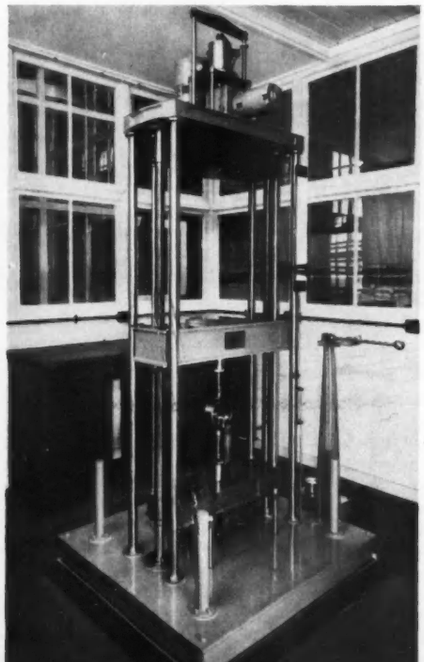


Fig. 1 Machine at operational level with proving ring in position for calibration in tension.

DESCRIPTION OF MACHINE

The machine, Fig. 4, consists of three main assemblies, A, the main earthed framework, B, the scale-pan assembly, and C, the weight carrier.

Main Earthed Framework. This is composed of the base 1, the centre frame 12 supported on four columns 5 and an upper frame 26 supported on four columns 24. The base carries a 3-h.p. electric motor and a reversing clutch gearbox 3 through which the drive is taken by the vertical shaft 6 to a two-speed gearbox 13 on the centre frame. The drive is then taken through the frame to a central screwed shaft 10. Mounted on the centre frame is the clutch-control lever 19. The upper frame carries a motorised screw jack 27 and a motor 28 which drives, through gears in the frame, the two screwed shafts 16.

Between the centre and upper frames is the centre beam 20, the upper surface of which is fitted with a platen 21 for use with compression instruments, the underside housing a spherically-seated adaptor 18 for use with tension instruments. The beam is carried on the two screwed shafts 16 from which it obtains its vertical adjustment.

Scale-Pan Assembly. The scale-pan assembly comprises two beams 14 and 25 situated one each side of the centre beam 20. The upper beam 25 has a platen 23 on the underside and is used for compression, while the lower beam 14 contains a spherically-seated adaptor 15 used for tension. The two beams are connected by four rods 17 and the scale pan proper 2 is suspended from the lower beam on four rods 9. When not in use, the whole assembly is supported by a bridge-piece 29 connected to the upper beam. The assembly is raised or lowered by means of the motorised screw jack 27. To restrict the rotation of the scale pan, each of the rods supporting the bridge-piece 29 is fitted with two ball-bearing guides. No other constraint has been permitted.

Weight Carrier. The weight-carrier assembly is between the base and the centre frame and is supported by a main frame 11 hung on the central screwed shaft 10. Attached to the main frame are six guide rods 8 which pass through guides in the base and centre frame. Attached to the guide rods are four sets of stepped triangular plates 7, the horizontal faces of the steps containing pins for supporting the weights. The plates can be seen in Figs. 2 and 3, which show the two extreme positions of the weight carrier. Attached to the weight carrier is an indicator 22 which shows the load on the scale pan.

Weights. The weights consist of 108 Parkerised steel plates 27 in. by 13 in. by 1·03 in., each weighing 100 lb. The dimensions adopted were determined by the capacity of the precision balance which was used to verify the weights. Each weight is fitted with two lugs on each long side, the underside of the lugs being in the form of one cone, one V-groove and two flats, a second flat being provided, in this instance, to prevent tilting of the weight as the lugs are disposed at the four corners of a rectangle. The lugs make contact with the pins on the stepped plates and ensure correct location of the weights when being removed from, or deposited on, the scale pan. The weights were machined to weigh slightly less than 100 lb. and were brought up to exact weight by the addition of steel balls which are housed in holes behind the stems of the lugs. The scale pan, weighing

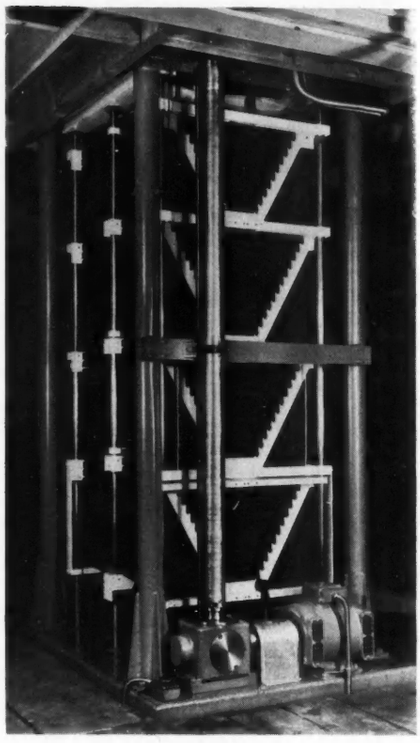


Fig. 2 Weights suspended on weight carrier.

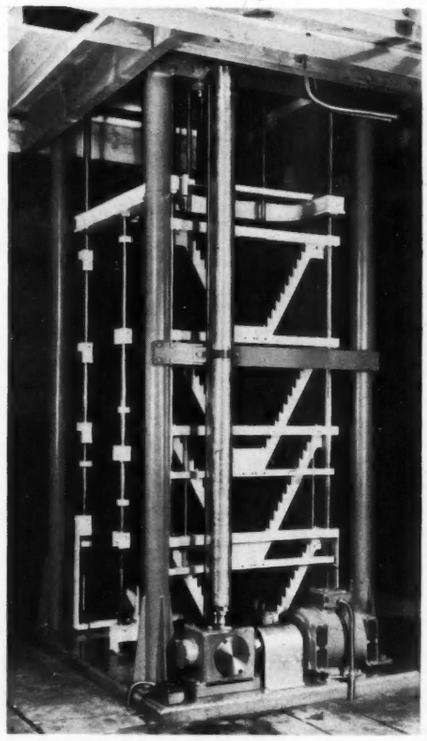


Fig. 3 Weights deposited on scale pan.

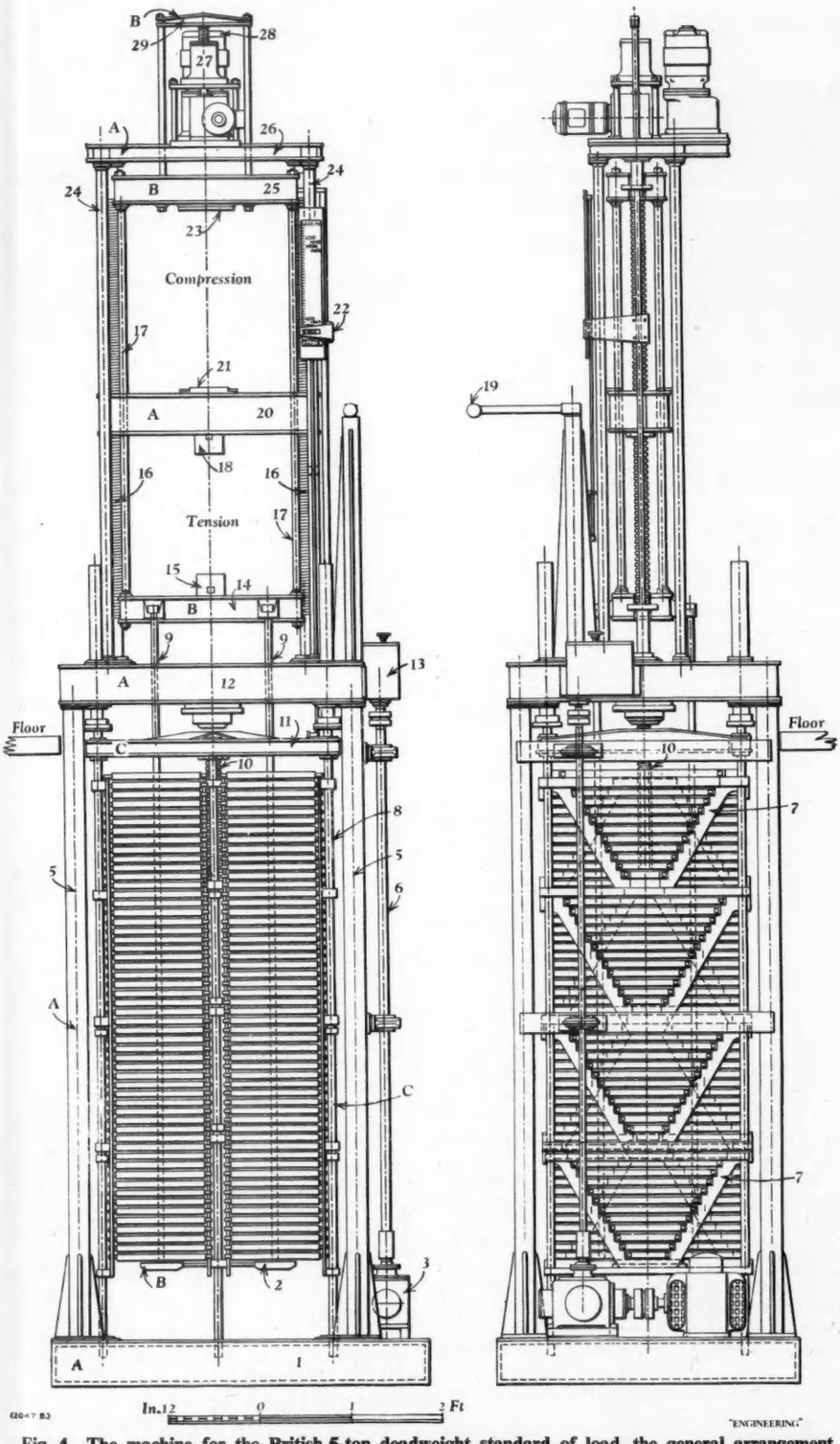


Fig. 4 The machine for the British 5-ton deadweight standard of load, the general arrangement of which is shown here, enables loads from 400 to 11,200 lb., to be applied in increments of 200 lb. Tensile or compressive loads can be applied with an accuracy of one part in 100,000.

400 lb., together with any additional weight, in pairs of 200 lb., can be regarded as having been correctly adjusted to within one part in 100,000 of the load applied. This adjustment was carried out in the Metrology Division of the Laboratory.

OPERATION OF MACHINE

The machine is housed in a temperature-controlled enclosure, the operational floor level being just below the centre frame (see Fig. 4). A control panel is conveniently situated for operation and includes the switch for the motor driving the weight carrier, reversing switches for raising and lowering the scale pan and the centre earthed platen, together with warning lights indicating the direction of travel. Some interlocking of controls is also incorporated. An instrument to be calibrated is placed in the machine between the upper platens if in compression or between the spherically-seated adaptors if in tension. A proving ring is shown in position for testing in tension in Fig. 1. The centre platen is adjusted to take up slackness in the assembly. The motorised screw jack supporting the scale-pan assembly is then lowered to its bottom limit allowing the minimum load of 400 lb. (due to the weight of the scale-pan assembly) to come on to the instrument.

To add further weights to the instrument the weight carrier is lowered, thus progressively depositing pairs of 100-lb. weights on to the scale pan. An indicator 22 at eye-level shows the load on the instrument at any time and also indicates when the added weights are clear of the carrier. The central screwed rod in the weight carrier which raises or lowers the weight is driven through the two-speed gear and the clutch. The clutch is of the duplex, multi-disc type running in oil, and the clutch-control lever at hand level controls the direction of travel and position of the weights. The two speeds of operation of the weight carrier are 2½ in. and 5½ in. per minute, respectively, the former being used when applying load. Limit switches are provided where necessary to prevent over-run.

The work described above has been carried out as part of the research programme of the Laboratory and this article is published by permission of the Director.

* * *

PHOSPHORUS FACTORY

A new factory for manufacturing phosphorus has recently been put into production at Portishead, Bristol, by Albright and Wilson, Limited, 49 Park-lane, London, W.1. It is expected to yield an annual production of over 40 million lb. of phosphorus. Much of this will be used in the company's Kirkby factory for the manufacture of sodium tripolyphosphate, hitherto largely imported from abroad, for making detergents. The factory will employ about 180 persons.

The new Portishead factory is situated on the south side of the Bristol Channel, facing one of the main power stations of the South Western Electricity Board. Two new wharves, 720 ft. and 600 ft. long, respectively, both having 60 ft. depth of water, have been constructed.

The main civil engineering and building contracts and the detail design and construction of the plant and buildings have been carried out by Simon-Carves, Limited, Stockport. The whole site area has been raised by about 2 ft. 6 in. to ensure against risk of flooding.

The main raw materials – phosphate rock and anthracite – are brought in by ship and are pneumatically unloaded by two suction pumps each driven by a 330-h.p. motor, on to a band conveyor. Granite chippings brought in by rail are unloaded on to the same conveyor, which transports the materials to eight 100-ft. high circular storage bins. The phosphate rock is stored in the bins and the granite chippings and anthracite are stored in the inter-bin spaces.

Unloading and conveying are controlled automatically, all the conveyors being interlocked. All the materials are dried before being automatically weighed and mixed. After mixing, the raw materials are conveyed to hoppers feeding by gravity into the processing furnaces. Six electric reduction furnaces, each taking 7,500 kW, are provided in a furnace house. Periodically, each furnace is tapped and the slag runs out into covered ways.

Phosphorus vapour mixed with carbon monoxide is continuously drawn off from the furnaces through dust extractors to condensers, where the phosphorus is condensed to liquid form. The carbon monoxide is returned either to the drying plant or the steam boilers as fuel. The liquid phosphorus is stored in heated underground chambers, whence it is pumped into tank wagons.

Fig. 1 Measuring the velocity of vibrations transmitted through a road. There appears to be a correlation between signal velocity and load-bearing capacity of the subgrade.

MEASURING THE LOAD-BEARING CAPACITY OF ROADS

A NON-DESTRUCTIVE TECHNIQUE

A test which has been used widely to investigate the strength of subgrades of road formation is that giving the California Bearing Ratio of the soil. This ratio is so called because it was originally developed by the Californian Department of Highways. As now used, this test is made by compacting a selected sample of material to a depth of 5 in. in a mould of 6 in. diameter. The density and moisture content of the sample as well as the degree to which it is compacted are chosen to correspond to those expected in actual service. After the sample has been compacted an annular weight equal to the weight of the road surface and other subgrade or soil above the layer under test is placed on the sample and the soil is subjected to penetration by a 1·95-in. diameter piston at a rate of 0·05 in. per minute. The loads required to effect penetrations of 0·1, 0·2, 0·3, 0·4 and 0·5 in. are observed and noted.

A graph of penetration against load can then be plotted and a corrected value for the pressure required to effect a penetration of 0·1 in. can be obtained. The ratio of this value to a pressure of 1,000 lb. per sq. in., which is roughly that required to effect a similar penetration in standard crushed rock, gives the Californian Bearing Ratio. Since this is normally expressed as a percentage, the California Bearing Ratio or C.B.R. is given by

$$\frac{\text{pressure for 0·1 in. penetration}}{1000} \times 100.$$

The above penetration shear test may be performed perfectly well on samples taken directly from the site of the road, but care must be taken to ensure that the sample is not, at the time of testing, in a condition particularly favourable to load bearing by reason of a long spell of good weather or similar circumstances.

Tests for bearing capacity of this nature are lengthy and require considerable care and skill in execution, if reliable results are to be obtained. Moreover, the figure given is dependent on the weight of overburden met in any particular case. Because the C.B.R. has been determined for a particular material under certain conditions, it does not necessarily – or even probably – follow that it will be the same under other conditions.

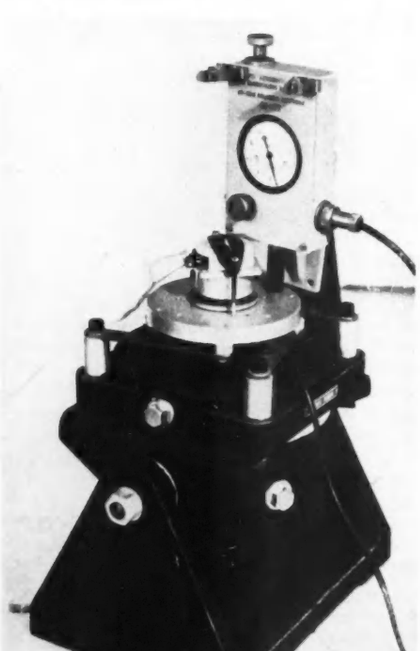
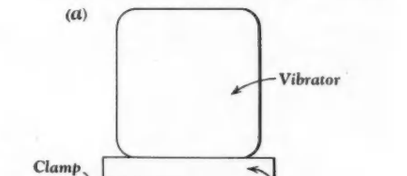


Fig. 2 The Goodmans vibrator being used to calibrate a seismic pick-up. This vibrator is a medium-duty model able to produce an alternating force of about 25 lb.

DETERMINATION OF WAVE VELOCITY

It would therefore seem to be highly desirable to use indirect tests to determine the C.B.R. if this is at all possible. The Road Research Laboratory of the Department of Scientific and Industrial Research are, in fact, working on this and similar problems in their laboratory at Harmondsworth, Middlesex. The electronic equipment shown in Fig. 1 above is used. A power amplifier supplies 40 watts at a frequency controllable between 40 and 2,000 cycles per second into a vibrator of the type made by Goodmans Industries Limited, Wembley. A typical model used is type 390a, which is shown in Fig. 2 being used to calibrate a seismic pick-up.



Figs. 3a and 3b By coupling the plunger of the vibrator to a leaf spring, its output can be increased if the vibrator is run at approximately the natural frequency of the spring. A series of springs, used either singly or in combination, covers the whole frequency range required.

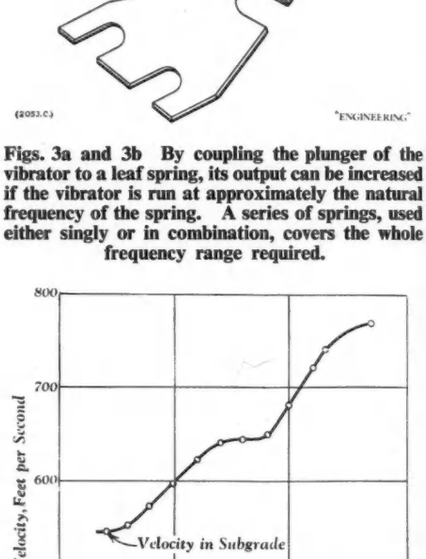


Fig. 4 Typical variation of velocity of Rayleigh waves in a three-layer road construction.

This vibrator is of the moving-coil type, having a plunger which oscillates in phase with the applied current of about 2 amperes, and can produce an alternating force of 25 lb.

For examination of road surfaces the vibrator is mounted on a baseplate as shown in Fig. 3a. To magnify the force of vibration transmitted to the road surface, the stiffness of the vibrator's coil suspension is increased by a steel leaf spring which tunes the mass of the coil and plunger so that the assembly is approximately in resonance at the frequency being applied to the vibrator. Fig. 3b is a detail of the spring. One end of this spring is rigidly clamped to the baseplate and the other end to the plunger of the vibrator. A series of springs of various stiffness is provided and, by using the springs singly or in combinations of two or more, a total of four or five springs have been found to cover adequately the frequency range from 40 to 500 cycles per second over which this work is at present being carried out.

The vibration is transmitted into the road surface through a bolt grouted into position, or by a similar rigid coupling. The vibration is then traced by a geophone or seismic pick-up

at measured distances from the vibrator. The signal from the pick-up is amplified and the wave form is displayed on a cathode-ray oscilloscope.

In order to obtain a fixed reference phase mark, a suitable circuit is used to blank out the oscilloscope trace for a short period at an identical point in each cycle of the output of the oscillator which is used to drive the power amplifier. As is illustrated in Fig. 1, the pick-up is moved in contact with the surface of the road radially away from the vibrator along a measuring tape, and the positions are noted at which the phase mark occurs at either the peak or the trough of the displayed waveform. The intervals between these positions are then equal to half the wavelength of the signal in its path between the vibrator and the pick-up. The distance moved by the pick-up between the coincidence of one peak or trough and the next with the phase mark on the screen is clearly equal to the wave length of the transmitted signal.

By varying the frequency applied to the vibrator, it is possible to obtain a table of the wavelengths at different frequencies, and multiplying the wavelength by the frequency gives the actual speed of the wave in the ground. The form of relationship between the wave velocity and the frequency of the applied vibration is illustrated in Fig. 4 for a three-layer road.

The results obtained show that, at low frequencies, the velocity is fairly constant and is, in fact, the velocity of Rayleigh waves in the subgrade. As the frequency increases a point is reached where the velocity begins to increase due to the influence of the base materials. The actual frequency at which this change occurs depends on the relative elasticities of the base and subgrade and on the thickness of the base. At much higher frequencies the properties of the road pavement affect the dispersion curve and ultimately, at very high frequencies, the velocity is determined solely by the physical properties of the pavement.

There is some evidence to indicate a correlation between the Rayleigh wave velocity in the subgrade and the California Bearing Ratio, and work on these lines is proceeding at the Road Research Laboratory.

A test takes only a short time and gives information on the properties of all strata making up the road. Even more important, the test is entirely non-destructive and can be carried out under actual operating conditions. It would thus be relatively simple to compare the properties of the road in summer and winter, when water-logged or frozen, or when compacted by a very heavy load passing over it.

Moreover, the values can be averaged over a wide area instead of having to depend for results on effective sampling techniques. It is possible to work the pick-up at distances of up to 50 ft. from the oscillator, checking the consistency of the materials all the way.

Finally, most road specifications lay down the methods to be used in their construction. This form of measurement may well provide a way in which the efficacy of different techniques can at once be tested. This applies not only to materials, but also to such factors as the weight and speed of rolling, the thickness of the pavement, etc.

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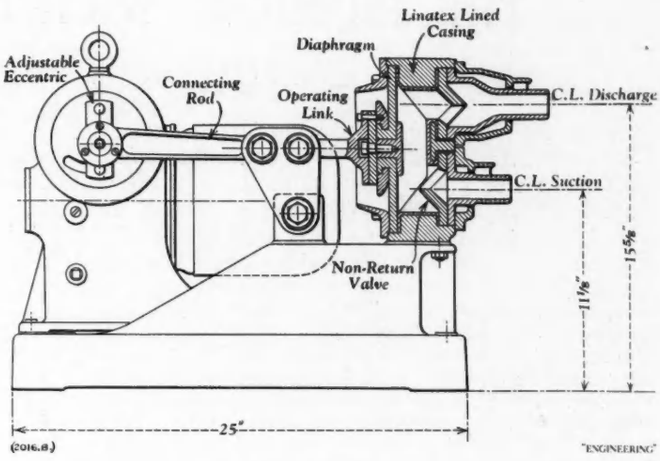
BULK-DELIVERY VEHICLE

A bulk-delivery road vehicle suitable for transporting grain, powder and similar materials has been introduced by Charrold, Ltd., 40, Trinity-square, London, E.C.3. It has been developed from the coal-delivery vehicle described in ENGINEERING, vol. 176, page 607 (1953), but it has a totally-enclosed container. It is made with or without the external conveyor.

The motor-driven Linatex pump, showing the corrosion-resistant diaphragm, suction and discharge connections and the drive through a worm-gear unit.



A DIAPHRAGM PUMP

For Chemical and Allied Industries

The Linatex self-priming diaphragm pump is made by Wilkinson Rubber Linatex, Limited, Camberley, Surrey, the concessionnaires of Linatex for Europe, and was primarily suggested by the demand for pump diaphragms made from Linatex owing to the corrosion-resisting properties of this material. One size of pump is at present being made, but in two forms as illustrated: one hand-operated and the other arranged for driving by a small electric motor.

The casing of the pump is an aluminium casting lined with Linatex; the diaphragm and valves are made from solid Linatex. The mushroom nut which, together with the diaphragm-retaining ring, serves to attached the diaphragm to the operating link, is of corrosion-resisting material, which is also used for both the inlet and discharge hose connections. It will be seen, therefore, that the interior of the pump is fully protected against corrosive liquids and there are no exposed metal parts within the pump chamber.

The diaphragm has a maximum movement of 1¾ in. and the nominal rate of discharge is 8 gallons a minute against a pressure-head of 25 ft. and a suction-lift of 10 ft.

In the motor-driven model the electric motor, which is of the totally-enclosed fan-cooled type, drives an adjustable eccentric through a worm-gear unit made by Opperman Gears, Limited, Newbury. This eccentric drives a connecting rod, the other end of which is pinned to a rocking-plate to which the end of the operating link of the diaphragm is also attached, the attachment being by means of flexible rubber bearings requiring no lubrication. Apart from the motor and gear unit, the only bearing requiring occasional lubrication is that connecting the adjustable eccentric to the connecting rod.

The gearing is such that the diaphragm makes 68 strokes a minute, but for particularly viscous liquids a gear unit giving 40 strokes a minute is available. In addition, the adjustment permits the stroke of the diaphragm to be varied up to its maximum of 1¾ in. to suit the viscosity of the liquid.

RESISTANCE TO CORROSION

The Linatex pump is resistant to a wide range of chemicals and effluents at temperatures up to 150 deg. F. When required to handle alkalis, the metal parts of the pump can be supplied in cast iron, while, for the handling of certain solvent oils, the diaphragm and valves can be supplied in an oil-resisting synthetic rubber.

The hand-operated Linatex pump.

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TWO-STAGE DIESEL FUEL FILTER

4 Gallons Per Hour Capacity

Clean fuel is one of the factors which makes for efficient operation of the fuel-injection pump and nozzles of a high-speed Diesel engine and helps to prevent excessive wear. For the purpose of cleaning Diesel fuel before it enters the pump the Automotive Products Company, Limited, Leamington Spa, have produced a combined two-stage fuel filter, the MF.5808. It is to be included in their range of Purolator filters for Diesel engines. Two filtering chambers are attached to a single head casting and can be detached for cleaning by removing a bolt passing through them. The head casting is drilled and tapped for mounting direct or by means of a bracket to the engine. The flow from the primary chamber, which contains a metal edge type of element for removing the large particles of foreign matter, to the secondary chamber, containing a plastic-impregnated paper element for removing the finer particles, is through channels in the head casting. The primary element can be cleaned in the normal way and the secondary element is of the expendable type requiring periodic replacement. The nominal rating of this unit is 4 gallons per hour.

THE PHYSICAL SOCIETY'S EXHIBITION

At the 38th exhibition of the Physical Society, being held at Imperial College, London, from April 8 to 13, there are 103 stands and the handbook describing the exhibits also gives particulars of those products of 22 other firms for which space could not be found. The times of opening are 10 a.m. to 8 p.m. on April 9 and 12, and 10 a.m. to 5 p.m. on April 10 and 13. Admission is by ticket only, obtainable (free) from the Physical Society, 1 Lowther-gardens, Prince Consort-road, London, S.W.7.

The Plessey Company, Limited, Ilford, Essex, are showing electronic equipment and a range of ceramic miniature components. The "Casfilm" miniature capacitors range in size from 4 mm. square to 12 mm. square for capacities of 0·001 to 0·01 microfarad respectively; alternatively, they can be supplied in a cylindrical form. With a thickness of 0·25 mm. they will operate up to 250 volts direct current at 70 deg. C. For higher capacities they may be stacked so that a unit of 0·1 microfarad capacity is 12 mm. square by 2·5 mm. thick. "Cascap" suppressor capacitors are of the disc type and range from 0·0005 to 0·005 microfarad. Proof voltage is 3,000 r.m.s. or direct current.

Tantalum electrolytic capacitors, the "Castanet" series, are 22 mm. diameter by 6 mm. high and have a capacity of 55 microfarad. With a direct-current leakage of less than 1 microampere at 20 deg. C., they can operate over a temperature range from —70 to + 150 deg. C. The working voltage is 70 direct-current with a peak ripple of not more than 8 per cent. "Casonic" transducer ceramics are based on a poly-crystalline form of barium titanate and can be fabricated in various shapes. There are three standard grades with slightly different properties. Conductive and permanent-magnet ceramics are also on show.

The Wheatstone Physics Laboratory of King's College, London, is showing a microtome for preparing ultra-thin sections for use with electron microscopes; specimens down to 0·03 μ in thickness may be cut. The specimen is advanced by controlled thermal expansion and moves in an elliptical path while the knife, part of a razor blade mounted on the edge of a water tank, remains stationary. The cut is made on the down stroke, at the point of minimum curvature of the path, and the specimen floats from the edge of the knife on to the surface of the water. It is then mounted directly on formvar-coated grids.

LOAD CELL

A means of measuring forces ranging from 5 cwt. to 200 tons is provided by the series of load-cells exhibited by Elliott Brothers (London), Limited, Lewisham, London, S.E.13. One of these cells is illustrated in Fig. 1. The force to be measured stresses a high-tensile steel member within the cell, bonded resistance wire strain gauges being attached to the member. The whole cell is hermetically sealed and provided with a cable gland. Excitation of the strain-gauge bridge is from a low-voltage source and the out-of-balance signal varies linearly with applied load. Calibration accuracy of the cells is within $\pm \frac{1}{4}$ per cent. of full load and they are self-compensating for temperature. The physical dimensions vary with the rating but are approximately 4 in. in height and diameter.

Servomex Controls, Limited, Jarvis Brook, Sussex, are showing a selection of voltage stabilisers for differing applications. They are also exhibiting a motor-controller unit working on the Velodyne principle, which compares a generator voltage with an internal reference voltage and applies any necessary correction to the field coils of the motor. This unit has a drift of less than 1 r.p.m. over many hours. The speed range is 1,000 to 1. One model gives a torque of 22 oz.-in. over its full speed range from 6 to 6,000 r.p.m.

Among the items on the stand of Isotope Developments, Limited, 120 Moorgate, London, E.C.2, is a thickness gauge for very light films and tissues. This is an industrial instrument for the continuous non-contact measurement of the thickness of sheet materials weighing less than 2·5 milligrams per square centimetre. The measurement is in terms of α-ray absorption by the sheet as it passes under a radiation source. Any width of material can be dealt with, and the accuracy is better than $\pm$ 1 per cent.

An instrument for counting microscopical particles is being shown by Mullard, Limited, Shaftesbury Avenue, London, W.C.2. It is designed to count particles ranging from 1 to 20 microns in diameter and was developed in conjunction with the National Coal Board to deal particularly with thermally precipitated dusts. The sample is examined by a cathode-ray tube flying-spot scanner through an appropriate optical system. Signals from the scanner are integrated so that each particle is counted only once. An elementary form of size analysis is also incorporated and provision is made for an "arrested scan" type of sizer.

Mullards are also showing the application of ultrasonic equipment to the cleaning of components where the standard of cleanliness must be high. The activity of cleaning baths, whatever agent is used, may be greatly increased by irradiation with ultrasonic vibrations. When the contaminant is an adherent film (as is the case when cleaning optical lenses) a frequency of 25 kilocycles is used, obtained from a magneto-strictor. When relatively loose particles have to be removed from inaccessible places (as in the cleaning of ball bearings, and similar components) then frequencies of the order of 1 megacycle are employed, obtained from a quartz-crystal transducer.

DRILLING BRITTLE MATERIALS

Another item on the Mullard stand is an ultrasonic drill for machining brittle materials. This is illustrated in Fig. 2. The drilling tool reciprocates at an ultrasonic frequency produced by a high-Q magnetostriction transducer, the vibrations being at a frequency of 15 kilocycles. A tapered metal stub, acting as a step-up velocity transformer, transmits the vibrations to a mild-steel tool tip screwed into the end. The amplitude obtained is large enough to allow comparatively rapid sinking and penetration of extremely hard, brittle materials such as tungsten-carbide, when an abrasive paste is fed to the tool tip. The hole produced is of any shape which can be formed on a mild-steel tip, not more 2 in. across.

The exhibits of Megatron, Limited, 115A Fonthill-road, London, N.4, include a selection of different types of electrically-conductive glass. The transparent coating is deposited by the firm's patented process of reactive cathodic sputtering. In one form, the film is gold sandwiched between layers of bismuth oxide; in commercial manufacture resistances down to 6 ohms per square can be obtained while retaining between 70 and 75 per cent. transparency. When semi-conducting compounds are used, resistances down to 50 ohms per square with transparencies of 85 per cent. can be obtained.

This firm is also showing a drive mechanism for vacuum or pressurised chambers, which does not use any rotating seals. The driving shaft imparts a circular motion to the end of a flexible metal bellows which are sealed to the tank wall, and thence to the driven shaft within the chamber. The device can be screwed to the wall of any vessel, using standard O-ring seals.

Electric and Musical Industries, Limited, Hayes, Middlesex, are showing a wide-band distributed amplifier having a band width of 80 megacycles and also an industrial television equipment. The three units comprising the latter are shown in Fig. 3. This is an Emitron equipment and can be safely operated by non-technical personnel. Being comparatively small, the camera can be used in many posi-

Fig. 1 This hermetically sealed load-cell measures 4 in. in height and diameter. Models are available for measuring loads between 5 cwt. and 200 tons.

Fig. 2 An ultrasonic drill for cutting hard brittle materials. A shaped mild-steel tip will cut corresponding holes in tungsten-carbide.

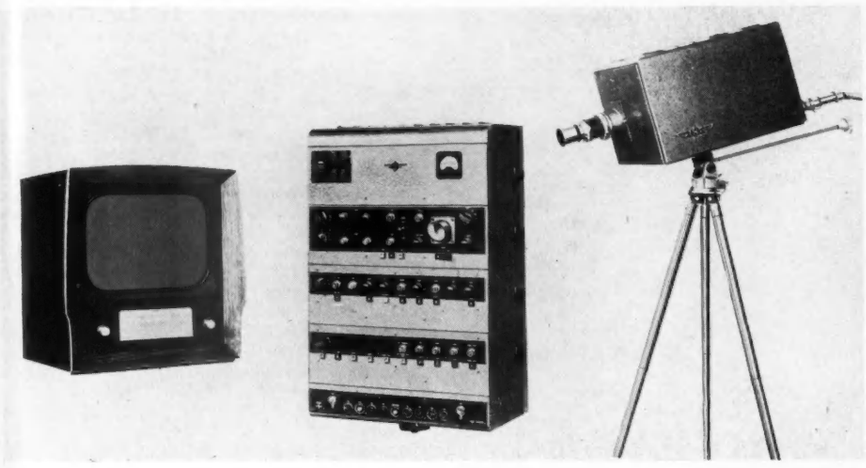


Fig. 3 The display, control and Emitron camera units of an industrial television equipment.

tions where remote metering is desired or is necessary. It also enables many observers in different places to view an operation at the same time.

Glass Developments, Limited, Sudbourne-road, London, S.W.2, are exhibiting the latest version of their Ultrasonoscope flaw detector. New accessories have been produced for this and consist of: transverse wave probes for single-probe work using barium titanate as the transducer material, and designed for thin sheet or tube; variable angle probes which enable the beam to be injected at any angle between 0 deg. and 50 deg. to the surface; and low-frequency probes also using barium titanate discs and intended for porous or coarse-grained materials.

A range of Magslips having smaller physical dimensions than earlier models, is being shown by Muirhead and Company, Limited, Beckenham, Kent. These are only 1½ in. in diameter and are available for supplies between 50 volts, 50 cycles, and 115 volts, 400 cycles. The company is also showing two-phase induction and split-field direct-current motors, of the same dimensions as the Magslips, and for use as servo-motors. Servo-amplifiers are also on exhibition.

The three divisions of Kelvin and Hughes, Limited, are all exhibiting items. The marine section is showing the "Kingfisher" echo-sounder for fishing, mention of which was made on page 117, *ante*. It is based on a combination of an electrolytic recorder and a cathode-ray tube viewing unit. Accurate soundings are given by supersonic vibrations of 30 kilocycles frequency, with a sounding rate of 100 per minute. The echos appear against calibrated scales, enabling the depth to be read off directly. The Kingfisher is available with ranges of 0 to 180 or 0 to 240 fathoms; the viewing unit can be adjusted to inspect any 15, 10 or 5 fathom layer beneath the ship, so that a scale as large as 1 fathom to 1 in. can be obtained. The recorder can be used separately, if desired, to give an outline of the bottom.

The Industrial Division of the firm is showing their Mark 5 miniature flaw detector, which is designed specifically for the inspection of welded pressure vessels where the equipment must be passed through a manhole; the small size also enables it to be used in many other applications. Completely self-contained, it measures 17 in. by 9 in. by 5 in. and weighs 28 lb. Frequencies between ¼ megacycle and 5 megacycles can be selected according to the type of material under test; the range represented by full deflection of the time-base can be varied between 2 in. and 12 ft. when using vertical probes. These distances are approximately halved when transverse-wave probes are being used. The scale can be expanded so that only a small part of the range is viewed at a time, enabling closely grouped flaws to be separated; the trace is bright enough to be observed in daylight. Standard instruments operated from a 200 to 250-volt, 50-cycle supply. A full description of the detector was given in ENGINEERING, vol. 175, page 363 (1953).

The Aviation Division is showing that by rotating the inner races of a pair of ball bearings in opposite directions, the friction torque reaction on the outer races is cancelled out except for the differences in the root-mean-square values of the friction torques. These may be further reduced by reversing the direction of rotation of both inner races at a period dependent on the inertia of the system carried by the bearings. This principle is demonstrated on the stand by a pendulum which can be kept swinging by rotating the races although the end load may be several pounds. Such a system would have advantages for the gimbal bearings of gyroscopes, by reduction in the level of the friction torque; elimination of the effects of torque peaks (by increasing the relative speed of inner and outer races); and reduction of the unbalancing effect of acceleration due to play in the conventional assemblies.

AIRCRAFT ALTIMETER

A radio altimeter for aircraft is being shown by Salford Electrical Instruments, Limited, Silk-street, Salford 3, Lancashire. This instrument gives the actual height of the aircraft above the ground to within close limits. The four parts of the equipment are shown in the illustration, Fig. 4. On the left is the transmitter/receiver; on the right at the top is the power unit and lower on the right are the indicator and control units. A second indicator can be fitted if desired. The altimeter works by reflections using a continuous wave, the frequency of which varies repeatedly in a saw tooth manner. Accuracy is ± 10 ft. at 200 ft. and within 3 per cent. of the indicated height up to 5,000 ft. Power consumption is approximately 130 watts at 24 volts direct current, and the units may be pressurised. It is possible to set the instrument for a desired height, when it will indicate visually any deviation therefrom.

The display by the Atomic Energy Research Establishment, Harwell, Buckinghamshire, includes a model of an electromagnetic pump for handling liquid metals such as mercury or sodium. The model is a perfect demonstration of Fleming's "left-hand rule" for determining the direction of motion of a conductor carrying a current in a magnetic field. A large direct current is passed between electrodes through the metal to be pumped, and a pair of magnetron magnets provide a field at right angles; the interaction produces a force and therefore the liquid metal moves along. Compensation for "armature reaction" is provided. The pump has no moving parts, and the liquid metal can be at a high temperature since all stationary parts can be metallic. The efficiency is reasonably high, but a very large current is required at a very low voltage.

To be continued

Fig. 4 Radio altimeter for mounting in aircraft. It measures accurately the height of the aircraft above ground level.

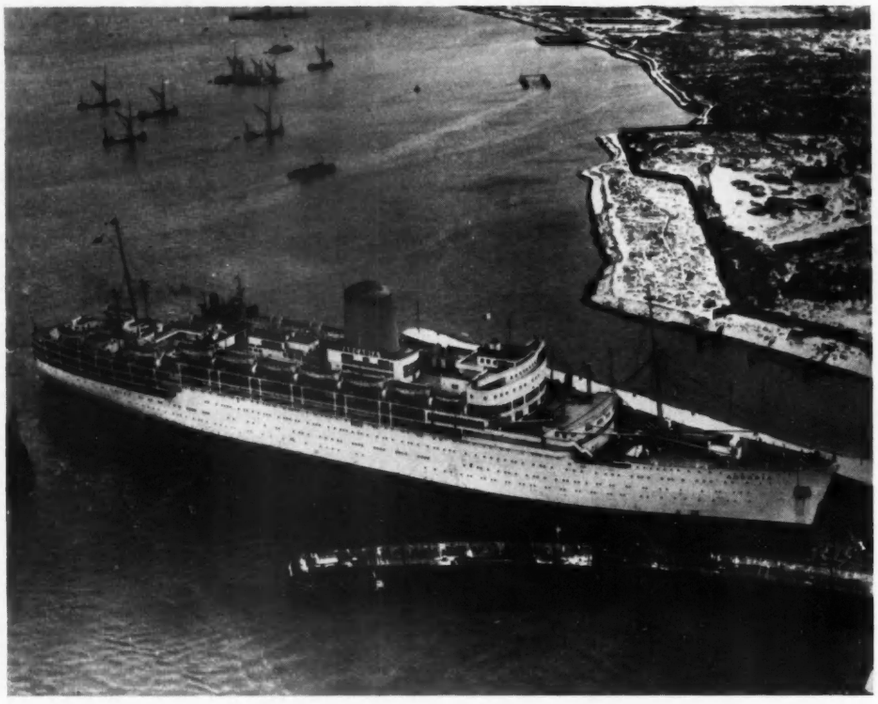


Fig. 1 The "Arcadia" berthing at Tilbury Docks on February 10 in preparation for her maiden voyage.

THE P. & O. LINER "ARCADIA"

DESIGN AND ACCOMMODATION

The twin-screw passenger and cargo liner Arcadia, of 29,734 tons gross, now on her maiden voyage between London and Sydney, N.S.W., is the first vessel of her type to be built by John Brown and Company, Limited, Clydebank, for the Peninsular and Oriental Steam Navigation Company, although it is more than 70 years since the P. & O. Company first went to Clydebank for a new ship. At that time, 1881, the Clydebank yard was owned by the brothers James and George Thomson. The vessel which they launched in that year for the P. &. O. service to Calcutta was the Thames, of 4,100 tons. Eighteen years later, the shipbuilding and marine engineering business of J. & G. Thomson passed into the ownership of John Brown and Company, but it was not until 1951 that the yard constructed another P. &. O. ship – the Singapore, which was followed by a sister-ship, the Sunda, in 1952; both are of 9,236 tons gross. The Arcadia, "the ship of the year," as she has been termed, therefore represents a big advance in the shipbuilding relations of the Clyde with the P. & O. Company.

The Arcadia, which is a sister-ship to the Iberia, now fitting out at Belfast, has the following principal dimensions: length overall, 720 ft., and between perpendiculars, 668 ft.; breadth moulded, 90 ft. 6 in.; depth to "C" deck, 49 ft. 9 in. She is designed to carry 679 first-class passengers, 735 tourist class, and a crew of 711, and has a cargo capacity of 211,000 cub. ft. for general cargo, and 158,500 cub. ft. of insulated space. Her twin-screw double-reduction geared-turbine machinery delivers 34,000 shaft horse-power, corresponding to a sea speed of 22½ knots. She is fitted with Denny-Brown stabilisers, and is the first P. & O. vessel to be so equipped.

The vessel has a raked stem and a cruiser stern. There are nine decks, namely, the boat deck, promenade deck, and decks "A" to "G," inclusive. The hull is constructed with a continuous double bottom for the full length between the forepeak and after peak tanks, and 10 water-tight transverse bulkheads, and is designed to remain afloat with any two adjacent compartments flooded. The double bottom, which is subdivided into 24 water-tight compartments, is used for the carriage of fresh water, reserve feed water, and water ballast or oil fuel; and fuel is carried also in wing bunkers extending from the tank top to the level of "G" deck, at the sides of the refrigerating-machinery compartments and the boiler room, as well as in athwartship deep tanks at the forward end of the boiler room. Additional deep tanks for fresh water are fitted in the wings abreast of the shaft tunnels. The fore peak can be used for either fresh water or for water ballast, but the after peak tank holds water ballast only.

General cargo is stowed in two holds and three 'tween-deck spaces, arranged forward and aft of the machinery spaces, and insulated cargo in three 'tween-deck spaces. The ship's stores are carried in 16 insulated chambers on "F" and "G" decks. Of the 15 watertight doors, four are power-operated and can be controlled from the bridge, from a position above the bulkhead deck, and locally at the doors themselves, from either side of the bulkheads in which they are fitted.

The hull structure is supported by four rows of pillars. A duct keel extends forward from the boiler room to No. 1 hold, and the second longitudinal is made oil-tight and water-tight from No. 3 hold to the after end of the engine room. Abaft the engine room, the centre girder is made oil-tight and water-tight. Solid floors are fitted at every frame, with three longitudinal girders on each side of the centre line. Most of the pillars are of built-up construction, in association with fabricated fore and aft girders.

ARRANGEMENT OF PASSENGER ACCOMMODATION

The first-class public rooms are situated on the boat deck and the promenade deck, and the tourist public rooms on "B" deck and "C" deck. The dining rooms for both first-class and tourist passengers are on "D" deck. The state-rooms for the first-class passengers are on decks "A" to "D" and those for the tourist-class passengers on decks "D," "E" and "F." In the first-class, there are 98 single-berth cabins, 241 with two berths, and 33 with three berths. The upper berths are of the Pullman type, and may be hinged up when not required; the same applies to the upper berths in the tourist accommodation, which consists of 78 two-berth cabins, five three-berth, 93 four-berth, and 32 with six berths each.

Included in the first-class accommodation, on "B" deck, there are two suites of cabins *de luxe* on each side of the ship, the after suite, on each side, having a private veranda.

The observation lounge for first-class passengers is situated at the forward end of the boat deck, and is provided with large windows giving a clear view forward. The other first-class public rooms are on the boat deck and comprise the lounge, a ball-room which can also be used for cinema displays, a veranda cafe, the library, two writing rooms which are also available for private parties, and the children's nursery. There is also an open-air swimming pool, with its own cafe adjoining.

The swimming pool for tourist passengers is also on the promenade deck. The tourist public rooms, all at the after end of the ship, comprise, on "A" deck, a screened gallery with bar on the port side, and a cinema room in the corresponding space on the starboard side. On "B" deck there is a ball-room, extending across the width of the ship except for a promenade on each side, a veranda with bar, and the children's nursery and play-ground. The tourist lounge and smoking room are on "C" deck.

Hospital accommodation for the first-class passengers is situated on "C" deck aft, on the port side. It includes male and female wards, a maternity ward, a surgery and operating room, and a dispensary. The tourist, crew and isolation hospitals are in a deckhouse at the after end of "B" deck.

A feature of the deck recreation spaces in both classes of accommodation is the liberal provision of glass screens, which can be opened or closed as necessary to suit the wind conditions. The sports deck, which occupies the central portion of the boat deck and has an area of 11,000 square feet, can be entirely enclosed if necessary, as also can the tourist deck spaces.

FIRST-CLASS PUBLIC ROOMS

The first-class public rooms in the Arcadia are among the pleasantest that we can recall in the passenger liners of recent years. There is nothing garish about the decoration – that phase, happily, seems to be passing rapidly, if it has not passed – and such symbolism as is incorporated is not obtrusive, but blends easily and harmoniously into the general scheme. By comparison with some post-war vessels, the designer (Mr. J. Patrick McBride, of Messrs. A. McInnes Gardner and Partners, Glasgow), almost seems to have imposed upon himself a severe restraint. The result, however, is one that it is eminently "easy to live with," which was a main objective of the P. &. O. Company. The extensive use of concealed lighting adds greatly to the restful appearance.

The observation lounge, situated, as previously mentioned, at the forward end of the boat deck, possesses various features of unusual interest. On three sides, the walls consist almost entirely of large windows, in front of which are arranged lounge chairs with footrests. Against the after wall is a small bar counter, flanked by models of ships' figureheads (stated to be based on actual originals) and, beside the doors leading to the boat deck, by two large wall panels. One represents the P. &. O. Company's first ship, the paddle steamer William Fawcett of 1829, and the previous Arcadia, built in 1888; and the other, the tea clipper Cutty Sark and a Chinese junk. In both, the draughtsmanship is as notable as the careful technical detail. The artist, Mr. Norman Howard, has been especially successful in capturing the peculiar and distinc-

Fig. 2 The library of the "Arcadia."

tive grace of the Cutty Sark. The panels themselves consist of large sheets of Warerite plastic, measuring 12 ft. wide and 8 ft. high. Two similar panels, decorated in colour with Venetian scenes by Mr. R. M. D. Robertson, are to be found in the veranda cafe on the promenade deck, and the same material is extensively used in the other public rooms and elsewhere.

On a central table in the observation lounge can be displayed charts showing the ship's course; and, for the information and interest of the passengers, there are also a Sperry repeater compass, a chronometer, and terrestrial and celestial globes. The windows are fitted with Venetian blinds, with aluminium slats.

At the forward end of the promenade deck is the children's nursery and "playground" and, aft of these rooms, the library, with a writing room on each side of it. The library (Fig. 2) opens out of the foyer, where are the lifts communicating with the first-class accommodation on the lower decks. All three rooms have screened windows on the forward side. From the foyer, on each side, wide entrance doors lead into the lounge, panelled in Canadian maple. This is an exceptionally spacious room, of the full width of the ship except for the promenade spaces outside.

Immediately aft of the lounge is a large dance floor which can be enclosed by folding glazed screens. These are fitted with black curtains for use when this space is required for cinema displays. From the dance floor, doors on each side lead to the veranda cafe, which also serves as the main bar and smoking room for the first-class passengers.

The pool cafe, adjacent to the open-air swimming pool, is served from the same bar as the veranda cafe, the two spaces being separated only by glazed screens, covered with metal filigree work. Other screens, of the folding type, protect the space round the pool from the weather.

MOTOR-ROTATED DOORS

The dining saloon, on "D" deck, is entered from a foyer by a revolving door on each side. These doors are of the usual hand-operated type, with the divisions at right angles. At the other end of the saloon there are two revolving service doors, but these have the divisions at 120 deg., to give ample space for the stewards to pass in and out when they are laden with trays, etc., and are revolved by electric motors. The saloon extends for the full width of the ship and is nearly 100 ft. long. The seating capacity is 366, arranged at tables for two, four or six persons. The room is air-conditioned. Walnut and sycamore veneers, and figured woods such as English cherry have been used for the panelling, relieved with metal work in silver bronze. The galleys are immediately abaft the saloon, on the same deck.

Fig. 3 First-class lounge.

A well-equipped shop and the ladies' and gentlemen's hairdressing saloons are on "A" deck, where also there is a bureau for handling passengers' mail. The purser's office, and a bureau for dealing with passengers' general affairs other than mail, are on "B" deck.

TOURIST-CLASS PUBLIC ROOMS.

The tourist-class public rooms, as mentioned, consist of a lounge, smoking room, dance floor, veranda, cinema room and gallery, dining saloon and a children's nursery. There is also a swimming pool and sports deck, both on the promenade deck. The lounge and smoking room are on "C" deck, the lounge being forward of the smoking room. The lounge has casement windows on each side and a wide glazed screen at the after end, separating the room from the entrance hall. A built-in bookcase contains the tourist-class library. The smoking room also is lighted by casement windows.

The dining saloon, on "D" deck, has accommodation for 376 people at tables for four, six or eight. Like the first-class dining saloon, it is air-conditioned, and is served by way of two revolving doors from the galley, which is forward of it. At the extreme after end of "D" deck, and separated from the dining saloon by a section of the tourist-class cabins, is the ship's laundry. In addition to this, however, there are special facilities in both classes of accommodation for passengers to undertake small items of personal laundry. These are equipped with deep sinks, draining boards and wringers, ironing boards, and electric irons; and, in each case, there is a heated room for drying and airing clothes.

The tourist passengers have their own shop, on the starboard side of "A" deck abaft the cinema room; and in a similar position on the port side of "A" deck is a hairdressing shop.

To be continued

* * *

LIGHTWEIGHT PLASTIC BELTING

High-Speed Drives

A new belting is being made from a synthetic material similar to nylon or perlon and marketed under the name of "Flexidur" belting by Aylesbury Turned Parts (True Screws), Limited, Britannia-street, Aylesbury. The belting can be supplied in any width either as endless belts or in lengths ready for jointing; the material is, however, of a standard thickness of 1 mm. (0·039 in.) and having a tensile strength of more than 850 lb. per inch width of belt. Due to its low specific weight, 0·23 lb. per square foot, the effect of centrifugal force at high speed is minimised and the belts have been used successfully at speeds in excess of 12,000 ft. per minute. A 4-in. wide belt running at 6,000 ft. per minute will transmit up to 75 h.p.

Flexidur is well suited to fixed-centre drives and the high flexibility of the material permits the belt to withstand 50 bends per second, which is of value for drives involving jockey pulleys, etc.

Joints in the belting are easily and quickly made by the application of an acid solution and belting is ready for use within two hours.

* * *

SHIP'S WINDOW

A new type of ship's window has been introduced by the Carron Company, Falkirk, in which a glass panel, supported at its lower edge on spring-operated lazy-tongs, slides in rubber-lined bronze guides fitted to the mild-steel window frame. A lever locking device holds the glass in any position by locking it against a rubber lining at the sill. When closed the glass is held by two spring clips at the top of the window.

The windows are weathertight and are produced in various sizes as a complete unit.

RESEARCH AND DEVELOPMENT WORK ON ELECTRIC WELDING

NEW LABORATORIES OF THE QUASI-ARC COMPANY LTD.

When the Quasi-Arc Company, Limited, commenced business in 1911, electric welding was a young industry with much to learn. Research on the problems of methods, materials and manufacturing processes was essential, and the company started on a research programme which has continued to the present day. Among the pioneering activities with which the company were associated were the building of the first all-welded ship, bridge and gasholder. Research continues, both on current problems and on future developments, and to enable this work to be carried out on the necessary scale the company have built and equipped extensive new laboratories at their works at Bilston, Staffordshire. The new premises were formally opened on March 31, by Mr. J. S. Hutchison, chairman of the British Oxygen Group of Companies, which is the parent concern of Quasi-Arc.

The Research and Development Laboratories at Bilston have a total floor area of about 11,000 sq. ft. There are two main sections, which deal with welding equipment and electrodes respectively, the latter section being housed in a newly-erected building. The work of the electrode section can be divided broadly into five groups: quality control of materials; new electrode development; research on electrode design and production; research on specific welding problems; and technical service to customers, which includes co-operation with other organisations.

CONTROL OF RAW MATERIALS

Quality control is exercised in co-operation with the works production departments, materials being checked both as received and at various stages during manufacture. Incoming supplies of raw materials, which include wire, minerals and solutions, are sampled on a proportional basis, the method used depending on the nature of the material. These samples are then checked against specifications of analysis, particle size, specific gravity, or other features as applicable. No material is passed to the works for use until it has been certified as correct in all particulars by the laboratories. Blending of powders is also controlled by sampling and analysis. Samples of wire and blended powders are then taken to the laboratories and trial electrodes are produced. These are tested for various qualities before bulk production is authorised. Periodical checks are also carried out during manufacture. In this way a complete history of every carton of electrodes produced is made available. The laboratories also provide facilities for carrying out approval tests as specified by various inspecting bodies.

ELECTRODE DEVELOPMENT

Research on the development of new electrodes is continuously in progress, both for welding new materials and for particular applications. For this purpose experimental electrodes are made in the laboratories, and exhaustive tests are then carried out on the deposition, metallurgical and physical properties of the electrodes. Ease of welding, slag detachability, fusion rate, covering strength, resistance to moisture absorption, and the metallurgical properties of the deposit are all studied. The suitability of the new electrodes for easy and economic production in quantity has also to be determined and the laboratories are responsible for providing the production departments with full details affecting production at every stage. This section of the laboratories is also concerned with the effects of very slight changes in material specifications. A test welding operation is shown in progress above.

Certain types of research are common to more than one electrode. Thus, for example, the present programme includes work on the extrudability of pastes, the strength of coverings, drying, and the hygroscopic qualities of covering materials. Investigations into the effect of hydrogen on weld-metal properties, low-temperature impact properties of welds and hot cracking of certain types of austenitic steels are also being carried out.

The laboratories spend a considerable amount of time on the investigation of problems or difficulties encountered by electrode users, and advising on materials and techniques. They do not undertake routine work of the type normally handled by a public test house, but are always prepared to investigate a particular problem connected with welding.

Test welding in progress in one of the bays adjoining the electrode development laboratory.

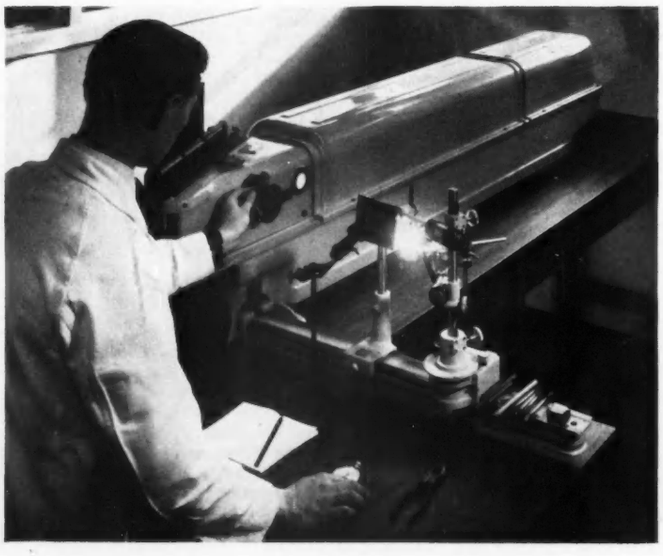
NEW LABORATORY BUILDING

The new laboratory block is a single-storey building, steel-framed and faced with red brick. It has a floor area of approximately 8,500 sq. ft. and is designed to accommodate a second storey at a later date. It is divided into eight main sections, with the necessary offices, library, dark rooms, metallographic-specimen preparation room, balance room, and stores. The main sections are equipped for: electrode development; chemical analysis; spectrographic analysis; mechanical testing; physical testing; metallography and petrology; X-ray diffraction; and industrial radiography.

The electrode development section is equipped with blenders, mixers, and extrusion machines of various kinds to enable the pilot production of electrodes to be undertaken. There are several electrode-drying ovens, including one with a maximum working temperature of 1,000 deg. C. Two annexes are provided for this laboratory, a test welding section, and a wire, powder and solution storage room, which contains grinding and sieving equipment.

The test welding section has four welding bays, which are used for examining experimental electrodes, for preparing test plates for batch testing and for official approval tests. They are fitted with Quasi-Arc alternating-current and direct-current equipment of various types up to 1,200 amperes per operator. The welding bays have their own control panels with a master panel which can be used to indicate any one of the bays. A large tinted observation window faces outwards into the main laboratory.

Chemical analysis is carried out in a large laboratory with north lighting, equipped for handling a wide range of work. Four island work benches are situated in the middle of the room, and the fume cupboards, titration racks, furnace benches, and general washing facilities are arranged round the walls. All the fume cupboards, except one containing an H_2S generator, have open fronts, doors being unnecessary, as a fan mounted on the roof provides sufficient



Operating the Hilger large quartz and glass prism spectrograph.

draught to clear both the cupboards and the laboratory. A vacuum pump is provided to serve all parts of the room. Weighing is carried out in a separate balance room which adjoins the main laboratory and is thermostatically controlled. It contains a number of aperiodic and Sartorious balances.

The spectrographic analysis section contains a Hilger large quarts and glass prism spectrograph (shown on the opposite page), a Judd-Lewis comparator, a photo-electric microphotometer, and a Spekker absorptiometer. The metallography laboratory adjoins the spectrographic laboratory and both share a common work-room. Equipment for the microscopic examination of metals and alloys includes a Vickers projection microscope, a binocular microscope and a general purpose metallurgical microscope.

Equipment for mechanical testing is housed in a room near the main entrance to the laboratories, and includes an Avery 100-ton hydraulic tensile testing machine, Izod and Charpy impact testing machines, a Wöhler fatigue machine, a Denison short-time stress-rupture creep machine, a Vickers diamond hardness tester, and a Magnaflux crack detector. Facilities are available for conducting tests at temperatures other than that of the atmosphere, as shown, for example, in the illustration below.

The physical testing laboratory adjoins that devoted to mechanical testing, and is equipped for work connected with heat-treatment of alloys, dilatometry, moisture absorption testing and measurement of robustness of electrode coatings. Three humidity cabinets are installed, with automatic control of temperature and relative humidity.

X-RAY EQUIPMENT

A Newton Victor Raymax X-ray diffraction unit, with a maximum output of 10 MA at 100 kV is installed in a separate room adjoining the industrial radiography laboratory. This latter contains a Newton Victor X-ray unit of 250 kV capacity, capable of dealing with mild steel up to 3 in. thick. It is suspended from a jib crane, which enables the tube to be set at any required working height, and to be swung to any position in the room. The room is constructed with cavity walls containing a rendering of barium sulphate plaster 1½ in. thick. Lead-lined sliding doors are provided with interlocking switches on the external control panel, so that the unit can only be operated from outside, with the doors closed.

A separate building is used for research in continuous welding processes. This work is carried out on behalf of the Quasi-Arc Company's associate, Fusarc Limited. This laboratory is fully equipped with the necessary machinery for the production of small quantities of experimental electrodes, and Fusarc and Unionmelt welding heads, supplied with alternating-current or direct current as required, are available for testing purposes.

Another separate building is used for the development of welding equipment and accessories. A section of this laboratory is equipped with a range of machine tools for the construction of mechanical prototypes. A fully-instrumented test panel is provided, to enable all electrical variables to be studied while welding equipment is under test.

Preparing a butt-welded specimen for impact test at −40 deg. C.

* * *

HYDRAULIC FRONT-TO-REAR LOADER

Overhead Action for Rapid Working in Confined Spaces

To simplify the loading of bulk materials, in conditions where space is limited and the rate of loading important, F. E. Weatherill, Limited, Union-row, London, N.17, have built a hydraulic "overloader." The action of the loader consists in swinging the loaded shovel, which is mounted on pivoted arms, through an overhead arc from the front of the tractor, where it is filled, to the rear, where it is discharged into a lorry or other receiver. The nature of this motion permits a simplification of the controls and a corresponding reduction in wear on clutch faces and operating mechanisms.

As can be seen in the accompanying illustration, the arms, which are of fabricated-steel box construction, are pivoted at a point just forward of the totally-enclosed driver's cab. A welded-steel structure running alongside the tractor bonnet supports a combined balancing load and front-bumper guard. The tractor's Diesel engine, which develops 44 brake horsepower at 1,800 r.p.m., supplies power for both loading and locomotion.

The operation of the hydraulic lifting mechanism is not continuous but introduces two separate pairs of rams. The arms are raised for the first part of their travel by a pair of main rams located towards the rear of the machine on each side of the frame. At the limit of their travel, a pair of secondary rams continue the action and complete the overhead movement of the side arms and scoop.

DISCHARGE ASSISTED BY BRAKING EFFECT

The lifting mechanism is arranged symmetrically on both sides of the vehicle. A triangular structure is formed by the lower part of one of the arms, a member pivoted at the same point as the arm and a secondary ram, which, as hypotenuse, links the other two sides. At the beginning of the lift the vertex situated at the pivot contains an angle of approximately 90 deg. During the initial raising of the arm, this triangle retains its shape and is rotated about the pivot by the operation of the main ram. In the second part of the movement, the hypotenuse is extended by the action of the secondary ram, thus deforming the triangle and completing the cycle.

The overhead action of this loader makes it simple to control, and one movement of a single lever governs the loading and discharging.

The entire loading and discharge operation is set in motion by one displacement of a single control lever. The action also includes an automatic braking effect which reduces the speed of the side arms as they approach the end of their travel. This precipitates the discharge of the scoop and increases the efficiency with which it is emptied. A further movement of the same control lever returns the scoop to the loading position under hydraulic power.

At no stage in the cycle do the arms travel past the operator and the safe handling of the machine is thereby enhanced. The load, however, must necessarily pass overhead and the cab is reinforced to provide protection from any spillage that might occur.

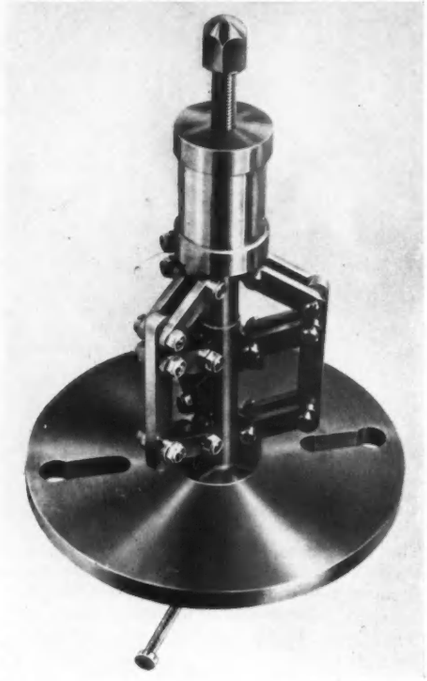
The lifting arms are of sufficient length to give ample height and reach for discharging into high-sided trucks and wagons and can be fitted with scoops of alternatively ¾ cub. yd. or 1 cub. yd. capacity. Digger teeth can be attached to the scoop if necessary.

CROWDING ACTION AND HIGH-SPEED LOADING

The filling of the scoop is assisted by two additional hydraulic rams, mounted on the arms, which cause a crowding action when the scoop is drawn through the material, thus increasing the speed of operation. The swinging action of the arms also raises the output of the loader and four cycles can be performed per minute. This permits a rate of loading, when suitable material is handled, of more than a 100 tons per hour. Moreover, the reduced number of gear changes and clutch pressures necessary adds to the speed at which all movements can be completed.

The overhead loading cycle also entails less steering effort than is required with conventional loaders and the new machine can work successfully in spaces too small or restricted for ordinary mobile shovels. It is suitable, for example, for use in tunnelling work, moving ships' cargoes as well as for road building and maintenance. The overloader is primarily a special-purpose machine, more limited in scope than a front-end loader but able to perform particular tasks in certain conditions with greater efficiency.

The hydraulic pump which feeds the rams is of the Vickers vane type and is driven directly from the engine crankshaft.



The Twinner pipe-flanging jig.

JIG FOR WELDING FLANGES TO PIPES

A new tool known as the Twinner pipe-flanging jig has been developed by Donald Ross and Partners Limited, 1-3 Arlington-road, London, N.W.1, to enable flanges to be welded square to the bore of pipes. It is also used for lining up " welding neck "-type flanges internally, for butt-welding to pipes.

In using the Twinner pipe-flanging jig, which is shown in the illustration above, the flange is pushed over the pipe. The jig is then inserted into the pipe and by turning the tommy bar the links are expanded to press against the inside wall of the pipe. As the links are always parallel the clamping plate is maintained square to the pipe.

The flange is secured by two bolts to the clamping plate and tack-welded on the outside. The jig is now removed, the internal weld completely made, followed by the external weld.

When used for welding neck flanges, the flanges are pushed over the links of the jig and the jig is inserted in the pipe and expanded. Lining-up the two components is automatic and a gap can be left to suit welding requirements. The complete weld can be made with the jig in position.

Twinner pipe-flanging jigs are of all-steel construction and are manufactured in five sizes to suit pipes ranging from 2 in. to 18 in. bore.

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GENERAL AND CONSTRUCTIONAL ENGINEERING

High-Frequency Electric Tools: Erratum

On page 397 of our issue of March 26 it was stated that certain new power tools would include " the first high-frequency electric tools to be made in the United Kingdom." This statement was, of course, erroneous. The Consolidated Pneumatic Tool Company, Limited, for example, have been producing " Hicycle " high-frequency tools for over 20 years and now make more than 50 different types.

AN ADAPTABLE CLAMPING SYSTEM

APPLYING EQUAL LOADS AT A NUMBER OF POINTS

A hydraulic clamping system, which enables equal predetermined loads to be applied to a fixture at any number of points, has been developed by Power Jacks Limited, Valetta-road, Acton, London, W.3. Known as the Newton hydraulic multi-point clamping system, it provides a flexible means of securing a wide range of components for welding, milling and other operations and consists of a hydraulic pump and a series of hydraulic plungers, linked by steel tubing.

Since a single pump supplies the pressure for all the plungers, a fixture employing this system is more quickly set than the conventional kind with separate locking screws. Not only is time saved but identical clamping conditions can be repeated. Moreover, the compactness of the plungers and cylinders enables them to be fitted in positions too inaccessible for ordinary methods of clamping.

In the illustration below are shown five plungers arranged in a welding fixture. Two of the plunger cylinders are held in a horizontal position by 4-bolt securing pieces and the other three are mounted vertically in special supports. The hydraulic pump, which can be seen on the left of the illustration is of the screw type and is fitted with a capstan handle. The fixture is loaded in two stages and the stop-valves shown at the left-hand side determine the sequence; when the rear valve is opened loads are applied by the vertical plungers, and the opening of the nearer stop-valve causes the horizontal plungers to operate. A few further turns of the hand pump are required when the second stage is introduced but this does not affect the pressure in the first stage.

LIMITING OF PLUNGER LOAD FOR WOOD AND OTHER SOFT MATERIALS

It is frequently necessary that the loads to be applied at the various points should not exceed certain critical values, and in this case dial gauges are included in the hydraulic circuit. Such critical loads depend on the nature of the material to be secured and are so limited to avoid crushing or distortion due to overloading. The system is therefore applicable to woodworking and to other industries where softness of materials or frailty of the structures to be held demands that great care be taken in the imposing of clamping loads.

The supply of hydraulic pressure is provided by either of two forms of pump: one is the screw type, already mentioned, and the other is lever operated. The screw pump is slower in action but capable of closer control than the lever type.

The pump can also be located at any distance from the fixture and thereby adds to the safety of the system when it is used in conjunction with machine tools. The screw pump can serve approximately six plungers and the lever pump eight or ten.

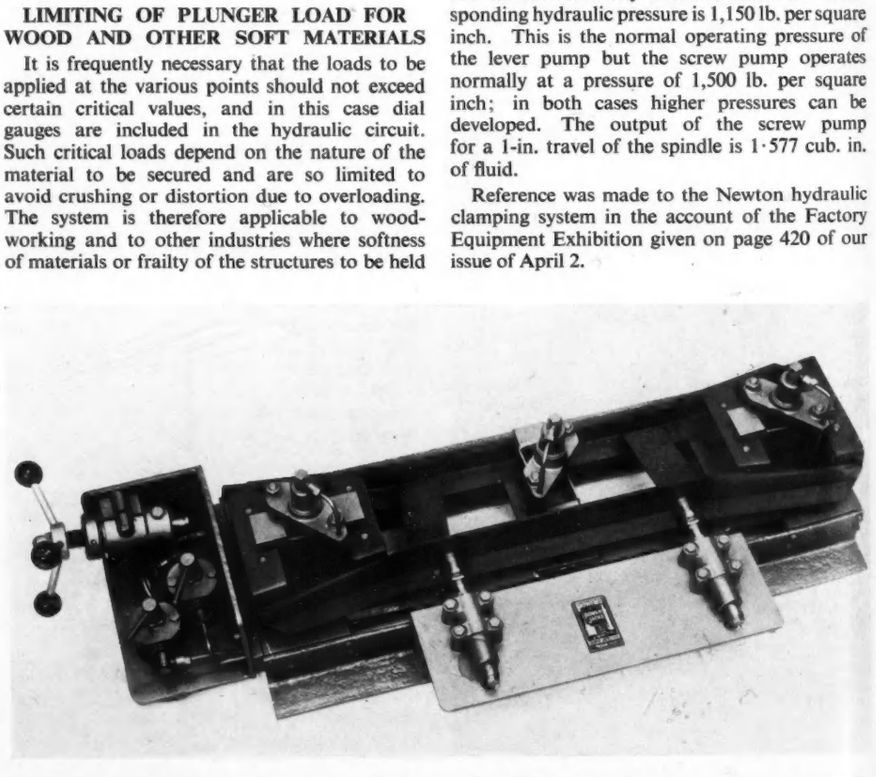
The plungers may be arranged to act directly on the workpiece or through a system of levers or ball cranks. Their simultaneous operation and equal loads enable the various components of a welded structure to be set evenly in position. The plungers are also released simultaneously and, as the hydraulic fluid returns to the pump container, they are retracted by the action of internal return springs.

COMPACTNESS OF PLUNGER UNITS

The plungers and cylinders are very compact and in the closed position measure a little more than 4 in. in length and 1 in. in diameter. Two versions are to be made, with plunger travels of 1 in. and ½ in., the latter already being in production; the plunger with the longer travel has been designed for use in those circumstances where greater space may be required for insertion of the workpiece. The weight of each plunger unit is ¾ lb.

A clamping load at the plunger button of 350 lb. can be safely obtained and the corresponding hydraulic pressure is 1,150 lb. per square inch. This is the normal operating pressure of the lever pump but the screw pump operates normally at a pressure of 1,500 lb. per square inch; in both cases higher pressures can be developed. The output of the screw pump for a 1-in. travel of the spindle is 1·577 cub. in. of fluid.

Reference was made to the Newton hydraulic clamping system in the account of the Factory Equipment Exhibition given on page 420 of our issue of April 2.



By means of the hydraulic plungers fitted to this welding fixture, equal clamping loads can be rapidly and simultaneously applied at several points.

Labour Notes

AGREEMENT ON ENGINEERING WAGES

Prospects in connection with the wage claims in the engineering industry have been distinctly brighter since the meeting between representatives of the Confederation of Shipbuilding and Engineering Unions and the Engineering and Allied Employers' National Federation on March 31, when general agreement was reached between the two sides that wages should be advanced by rather more than 6 per cent.

The Federation undertook to advise local associations of employers to accept the proposals and a similar recommendation was due to be made by the Confederation's leaders at a meeting of executive officials of affiliated unions at York yesterday. It appears to be almost certain that the increase will be accepted by both sides and, in that case, well over 2,500,000 engineering employees will receive higher wages ante-dated to April 5. These increases are estimated to cost the employers between 60 and 70 million pounds a year.

It is proposed that the consolidated time rates of adult skilled operatives shall be advanced by 8*s.* 6*d.* a week, those of semi-skilled men by 7*s.* 6*d.* a week, and those of unskilled employees by 6*s.* 6*d.* a week. Proportionate increases are expected to be granted to women and juveniles.

There had been no signs, previous to the meeting, that agreement might be reached. The employers' Federation had stated very definitely that it was not prepared to offer more than the increases put forward on March 17, which amounted to 7*s.* 4*d.* for adult skilled men and advances in proportion for other grades.

It appears that the leaders of the Confederation attended the meeting prepared, for the first time, to accept less than the 15 per cent. increase demanded in April last year, and that the Federation's officials were willing to offer 8*s.* 3*d.* a week for the skilled grades. Some bargaining then ensued and, as stated, this was concluded by the skilled grades being granted an increase of 8*s.* 6*d.* a week, 1*s.* 2*d.* more than was offered on March 17.

SHIPBUILDING WAGES INCREASED

Increases identical to those conceded in the engineering industry were recommended for employees in the shipbuilding and ship-repairing industries at a meeting between representatives of the Shipbuilding Employers' Federation and the Confederation of Shipbuilding and Engineering Unions on April 1. As in the case of the engineering industry, it is expected that, if the recommendations are accepted by the member-firms of the Federation and by the shipbuilding unions affiliated to the Confederation, there will be proportionate increases for women and juvenile employees. The higher rates are due to take effect from April 5, and it is expected that, in all, some 220,000 employees in the shipbuilding and ship-repairing industries will benefit.

Although some trade-union leaders have expressed disappointment that the increases are not larger, there is every likelihood that the proposals will be accepted. In the main, such disappointment as exists has been confined to the officials of unions catering for unskilled workpeople. The shipbuilding employees, like their engineering colleagues, originally asked for increases of 3*s.* in the pound.

RAILWAY SHOPMEN'S WAGES

An unexpected hitch arose last week in connection with the proposals for higher wages for railway shopmen employed on British Railways. On March 26, the British Transport Commission offered flat-rate increases of 8*s.* a week for adult craftsmen, 7*s.* 6*d.* a week for other adult men, and proportionate increases for women and juveniles.

Representatives of the Confederation of Shipbuilding and Engineering Unions and the National Union of Railwaymen, to which the railway shopmen belong, agreed to consult the executive bodies of their respective organisations on the proposals and it was generally expected that the Commission's offer would be accepted as it stood.

Although the unions' executives seem to be prepared to accept the Commission's proposed increases, some dissatisfaction appears to have been expressed by the unions' executives regarding the date of their coming into force.

The Commission had suggested that the higher rates of pay should date from early in January, when the general grades of railwaymen received their 6 per cent. increase. This left out of count the fact that these grades received an increase of 4*s.* a week, as from early in December, in accordance with an award of the Railway Staff National Tribunal. At the meeting last Monday between representatives of the Commission and officials of the unions concerned, the trade-union leaders were expected to draw attention to this discrepancy, and to suggest that the shopmen should receive some extra amount, to correspond to the 4*s.* paid to the general grades between early December and the date in January when the 6 per cent. increase came into force.

THREATS OF RAILWAY STRIKE ACTION

A much more serious crisis has arisen in connection with the separate negotiations, between the British Transport Commission and the three principal railway unions, on the question of setting up a new wage structure for railway employees.

Discussions on the whole structure of wages and salaries, and an investigation into anomalies, were agreed to by the Commission last December as a condition of the National Union of Railwaymen cancelling its instructions for a national strike. The third of a series of meetings on the subject, between officials of the Commission and representatives of the N.U.R., the Associated Society of Locomotive Engineers and Firemen and the Transport Salaried Staffs' Association, took place in London on April 1, under the chairmanship of Sir John Benstead, the Commission's vice-chairman. Although the meeting lasted for nearly four hours, little progress was achieved and each union decided to consult its executive body.

On the following day, April 2, the A.S.L.E.F. announced that it had decided to call a strike of the 70,000 footplate men belonging to that union as from midnight on Saturday, April 24, unless, prior to that date, the Commission had produced definite proposals for revising the wage structure of British Railways. The N.U.R., which is understood to have nearly 20,000 footplate men among its 400,000 members, stated that it was not associated with other union's threatened action and that it did not regard the negotiations on the wage structure as having broken down.

DIFFICULTIES OVER DIFFERENTIALS FOR SKILLED GRADES

In addition to the immediate implementation of the increase of 4*s.* a week, the agreement between the Commission and the three principal railway unions on December 16, 1953, provided that ways should be sought to improve the efficiency of the railway service, that there should be a further wage increase on a percentage basis within two months, and that there should be a complete examination of the industry's wage and salary structure.

The Commission announced at the time that the investigation of the wage and salary structure should be exhaustive and without conditions of any kind. Its object would be to correct anomalies, to provide increased incentives (including differentials) and to examine standard rates of pay.

By January 7, all three unions, at the Commission's invitation, had put forward their individual proposals, and, since then, three meetings between the representatives of the Commission and the unions have been held to discuss the problem. At none of these, however, has the Commission presented suggestions of its own, although, apparently, it has been strongly urged to do so by the A.S.L.E.F. and the T.S.S.A. The position seems to be that difficulty of reconciling the widely differing views of the three unions have presented the Commission with an awkward problem.

The N.U.R. proposed that the existing minimum weekly rate of £6 4*s.* 6*d.* should be increased to £6 15*s.*, and that there should be advances of 2*s.* 6*d.* for each of the higher grades, which should be reduced in number. This would provide a maximum rate of £9 15*s.* a week, for senior engine-drivers. The A.S.L.E.F. is anxious for the differentials for engine-drivers and firemen to be restored to their pre-war level, and its proposal was that the maximum rate for engine-drivers should be £10 5*s.* a week. The T.S.S.A. has asked for separate negotiations altogether for the clerical grades. It considers that the wages of its members should not be tied to those of the conciliation grades.

The Commission has taken the view that the Unions should first determine among themselves what the minimum rate of pay should be and that negotiations on a new wage structure should be conducted with that rate as the basis.

HIGH WAGES NO SOLUTION TO LIVING COSTS

A sharp warning that increases in wages provided no lasting solution to the problem of meeting high living costs, if prices rose as well, was given by Mr. Arthur Deakin, C.H., the general secretary of the Transport and General Workers' Union, at a conference on "Incentives in Industry" at the University College of North Staffordshire, Keele, Stoke-on-Trent, on April 4.

He said that the realisation of this truth was seeping in among employees generally. The real solution to the high cost of living, if only the means could be found of bringing it about, would be to stabilise prices and then improve the value of money.

Suggestions that the collective bargaining system between unions and employers should be further developed, so that all wages and conditions of work should be settled by voluntary negotiation, and all disputes by constitutional machinery, were being closely studied by the Trades Union Congress. Mr. Deakin said he believed that such procedure would constitute another step towards creating a real industrial democracy. The confidence of employees in arbitration had been shaken recently as a result of unfortunate decisions based on "sheer materialism." That confidence had to be restored. Industry had reached the age of reason and, personally, Mr. Deakin concluded, he was in favour of making the most of arbitration.

Many speakers at the conference, which was organised by the Stoke-on-Trent Branch of the Institute of Personnel Management, agreed that, although wages and salaries were still the greatest of all incentives, there were other urges to greater effort besides those of a purely financial character.

NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

LONDON
"Battery-Operated Vehicles," by E. G. Barton. Lighting Service Bureau, 2 Savoy-hill, W.C.2. Tues., April 13, 6.30 p.m.

British Institution of Radio Engineers

LONDON
"Crystal Valves in Radio and Electronics," by B. R. A. Bettridge. London School of Hygiene and Tropical Medicine, Keppel-street, W.C.1. Wed., April 21, 6.30 p.m.
NEWCASTLE-UPON-TYNE
"Electro-Encephalography," by Professor Alexander Kennedy and J. W. Osselton. North-Eastern Section. Neville Hall, Westgate-road, Newcastle-upon-Tyne. Wed., April 14, 6 p.m.

Chemical Society

DUNDEE
"Change of Scale of Chemical Reaction," by Dr. S. J. Green. St. Andrews and Dundee Branch. Chemistry Department, University College, Dundee. Fri., April 16, 7 p.m.
LIVERPOOL
"The Story of the *iso*Quinoline Alkaloids," by Dr. R. H. F. Manske. Centenary Lecture. Joint meeting with other societies. Chemistry Lecture Theatre, The University, Liverpool. Fri., April 23, 5 p.m.

Illuminating Engineering Society

LONDON
"Illuminants for Colour Reproduction and Printing," by H. M. Cartwright. London School of Hygiene and Tropical Medicine, Keppel-street, W.C.1. Tues., April 13, 6 p.m.

Incorporated Plant Engineers

BLACKBURN
"Thermal Insulation in the Medium-Temperature Range," by C. Jolley. Grosvenor Hotel, Lord-street, Blackburn. Thurs., April 15, 7.30 p.m.
BRISTOL
Discussion on "The Gas-Turbine Locomotive." Western Branch. Grand Hotel, Bristol. Wed., April 21, 7.15 p.m.
GLASGOW
"Hospital Heating: Modern Methods," by W. Russell. Scottish Building Centre, 425-427 Sauchiehall-street, Glasgow. Wed., April 21, 7 p.m.
MANCHESTER
Discussion on "The Protection of Timber from Woodworm and Dry Rot." Engineers' Club, Albert-square, Manchester. Tues., April 13, 7.15 p.m.
NOTTINGHAM
Various short papers. East Midlands Branch. East Midlands Gas Board's Showrooms, Parliament-street, Nottingham. Wed., April 14, 7 p.m.
ROCHESTER
Discussion on "Self-Oiling Bearings." Kent Branch. Bull Hotel, Rochester. Wed., April 21, 7 p.m.

Institute of British Foundrymen

BRADFORD
Annual General Meeting. West Riding of Yorkshire Branch. Technical College, Bradford. Sat., April 24, 6.30 p.m.
BRISTOL
Annual General Meeting. Bristol and West of England Branch. Grand Hotel, Bristol. Sat., April 24, 3 p.m.
IPSWICH
"Operating Experiences with Hot-Blast Cupolas in Great Britain," by F. C. Evans. East Anglian Section. Public Library, Ipswich. Tues., April 13, 7.30 p.m.
LINCOLN
"Mechanical Aids to Production," by H. Haden. Lincolnshire Branch. Lincoln Technical College, Lincoln. Thurs., April 15, 7.15 p.m.
Short Paper Competition. Lincolnshire Branch. Lincoln Technical College, Lincoln. Thurs., April 22, 7.15 p.m.
MANCHESTER
Annual General Meeting, Short Paper Competition, and Foundry Brains Trust. Lancashire Branch. Engineers' Club, Albert-square, Manchester. Sat., April 24, 3 p.m.
SOUTHAMPTON
"Methods Employed in the Production of Heavy Iron Castings," by J. Richardson and C. F. Lawson. Southampton Technical College, St. Mary-street, Southampton. Thurs., April 22, 7 p.m.

Institute of Fuel

NEWCASTLE-UPON-TYNE
"Atomic Energy," by R. V. Moore. North-Eastern Section. King's College, Newcastle-upon-Tyne. Mon., April 12, 6.30 p.m.
NOTTINGHAM
"The Future of Our Power Supplies," by Professor F. E. Simon. East Midland Section. East Midlands Gas Board's Showrooms, Parliament-street, Nottingham. Thurs., April 22, 6.15 p.m.

Institute of Marine Engineers

LONDON
"British Naval Gas Turbines," by Commander (E) G. F. A. Trewby. Tues., April 13, 5.30 p.m.
WEST HARTLEPOOL
"Water Treatment," by J. T. Aynsley. North-East Coast Section. Technical College, West Hartlepool. Thurs., April 22, 7 p.m.

Institute of Marine Engineers and Institution of Naval Architects.

COWES
"Prefabrication of Welded Ships' Structures," by R. Cousland. Southern Joint Branch. J. Samuel White & Co., Ltd., East Cowes Shipyard, Isle of Wight. Sat., April 10, 1.40 p.m.

Institute of Petroleum

LONDON
"Design and Manufacture of Welded Pressure Vessels," by T. B. Webb. Wed., April 14, 5.30 p.m.

Institute of Road Transport Engineers

LONDON
"Some Factors Affecting Fuel Consumption," by W. T. Skinner. Royal Society of Arts, John Adam-street, Adelphi, W.C.2. Thurs., April 22, 6.30 p.m.
WIGAN
Annual General Meeting. North-West Centre. Victoria Hotel, Wigan. Wed., April 21, 7.30 p.m.

Institution of British Agricultural Engineers

LONDON
Discussion on "Avoidance of Choking in Ploughs." Institution of Electrical Engineers, Savoy-place, Victoria-embankment, W.C.2. Tues., April 13, 2.15 p.m.

Institution of Chemical Engineers

LONDON
Symposium on "Fuel and Power in the Chemical Industry." Graduates' and Students' Section. Battersea Polytechnic, S.W.11. Fri., April 23, 9.30 a.m.
Annual General Meeting. Graduates' and Students' Section. University College, Gower-street, W.C.1. Sat., April 24, 10 a.m.

Institution of Civil Engineers

LONDON
"Extensions at Takoradi Harbour," by A. J. Clark and J. H. A. Broughton. Maritime and Waterways Division. Tues., April 13, 5.30 p.m.

Institution of Electrical Engineers

LONDON
Discussion on "Safety Measures for Radio and Television Equipment," opened by E. P. Wethey. Informal Meeting. Mon., April 12, 5.30 p.m.
"Safety in the Use of Portable and Transportable Electrical Equipment in Industry," by J. Bunting. Utilization Section. Thurs., April 22, 5.30 p.m.
Discussion on "A Method for the Plotting of Magnetic Fields Due to Currents," opened by Dr. F. T. Chapman and D. G. Sandeman. Education Discussion Circle. Fri., April 23, 5.30 p.m.
Address by the President, H. Bishop. London Students' Section. Tues., April 13, 6.30 p.m.
LEEDS
Faraday Lecture on "Electro-Heat and Prosperity," by O. W. Humphreys. North Midland Centre. Town Hall, Leeds. Mon., April 12, 7 p.m.
NEWCASTLE-UPON-TYNE
Annual General Meeting and Conversazione. North-Eastern Centre. Royal Station Hotel, Newcastle-upon-Tyne. Mon., April 12, 6.15 p.m.

Institution of Engineers-in-Charge

LONDON
"Developments in Iron and Steel Production at Port Talbot," by I. S. Maxwell Scott. St. Bride Institute, Bride-lane, Fleet-street, E.C.4. Wed., April 14, 6.30 p.m.

Institution of Engineers and Shipbuilders in Scotland

GLASGOW
Annual General Meeting. "Investigations on Surface Finish of Steel Shafts," by Professor A. S. T. Thomson, Professor A. W. Scott, W. Ferguson and G. V. Stabler. Tues, April 13, 6.45 p.m.

Institution of Locomotive Engineers

LONDON
"Locomotive Diagramming and Utilisation," by L. C. Welborn. Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, S.W.1. Wed., April 21, 5.30 p.m.

Institution of Mechanical Engineers

LONDON
"Tyre Characteristics as Applicable to Vehicle Stability Problems," by T. J. P. Joy and D. C. Hartley. Automobile Division. Tues., April 13, 5.30 p.m.
James Clayton Paper on "A New Frontier: Air-Pollution Control," by Frederick S. Mallette. Fri., April 23, 4.15 p.m.
BIRMINGHAM
"Some Practical Applications of Strain Gauges in Industry," by J. R. Bryant. Midland Branch. James Watt Memorial Institute, Birmingham. Thurs., April 15, 6 p.m.
CARDIFF
"Sampling Chimney Emissions and Pulverised Fuel," by E. Hywel Jones. South Wales Branch. South Wales Institute of Engineers, Park-place, Cardiff. Tues., April 13, 6 p.m.
LEEDS
"Operating Experiences with a 750-kW Gas Turbine," by G. B. R. Feilden. North-Eastern A.D. Centre. Chemistry Lecture Theatre, The University, Leeds. Wed., April 21, 7.30 p.m.

Institution of Mining and Metallurgy

LONDON
"The Production of Asbestos in South Africa," by W. E. Sinclair; and "Geochemical Prospecting at Mount Isa, Queensland," by A. H. Debnam. Geological Society's Apartments, Burlington House, Piccadilly, W.1. Thurs., April 22, 5 p.m.

Institution of Production Engineers

LONDON
"Machine Tool Replacement," by T. P. N. Burness. London Graduate Section. Tues., April 20, 7.15 p.m.
BIRMINGHAM
"Mechanical Handling," by F. T. Dean. Birmingham Graduate Section. James Watt Memorial Institute, Birmingham. Tues., April 13, 7 p.m.
"The Training of the Young Engineer," by J. Wilson. James Watt Memorial Institute, Birmingham. Wed., April 21, 7 p.m.
CREWE
"The Development of Iron and Steel Tube Manufacture," by G. R. Goldsworthy. Stoke-on-Trent Section. Mechanics' Institution, Crewe. Tues., April 13, 7.30 p.m.
DERBY
"Ferrous Die-Casting," by H. A. Redshaw. Irongates Hotel, Irongate, Derby. Mon., April 12, 7 p.m.
EDINBURGH
Film Evening. North British Station Hotel, Edinburgh. Wed., April 14, 7.30 p.m.
LUTON
Discussion on "Production Control in the Small Firm." Luton Graduate Section. Luton Library, Williamson-street, Luton, Bedfordshire. Wed., April 14, 7.30 p.m.
NEWCASTLE-UPON-TYNE
Open Meeting. North-Eastern Section. Neville Hall, Westgate-road, Newcastle-upon-Tyne. Mon., April 19, 7 p.m.
OXFORD
"Plastic Components: Methods of Manufacture and Advantages in Their Application," by G. F. Meades. Tues., April 13, 7.15 p.m.

Institution of the Rubber Industry

LONDON
Annual General Meeting and Film Evening. Royal Society of Tropical Medicine and Hygiene, 26 Portland-place, W.1. Tues., April 13, 7 p.m.
BIRMINGHAM
Discussion on "Use of Rayon in Tyres," by G. Roelofs. Midland Section. Fort Dunlop, Birmingham. Mon., April 12, 6.30 p.m.
LEICESTER
Annual General Meeting and Film Evening. Bell Hotel, Leicester. Fri., April 23, 7.30 p.m.
PRESTON
Annual General Meeting. Bull and Royal Hotel, Preston. Mon., April 12, 7.15 p.m.

Institution of Structural Engineers

LONDON
"Fatigue of Welded Structures," by Dr.-Ing. R. Weck. Thurs., April 22, 6 p.m.
GLASGOW
Annual General Meeting. Scottish Branch. Ca'doro Restaurant, Glasgow. Tues., April 13, 6 p.m.

Junior Institution of Engineers

LONDON
"Engineering Maintenance in a Paper Mill," by N. A. Holmes. Townsend House, Greycoat-place, S.W.1. Fri., April 23, 7 p.m.
SHEFFIELD
"Choosing and Using Special Steels," by A. V. Jobling. Livesey Clegg House, Union-street, Sheffield. Mon., April 12, 7.30 p.m.

Liverpool Engineering Society

LIVERPOOL
Annual General Meeting. Wed., April 14, 6 p.m.

Newcomen Society

LONDON
"Lincolnshire Windmills: Part II, Tower Mills," by Rex Wailes. Science Museum, Exhibition-road, South Kensington, S.W.7. Wed., April 14, 5.30 p.m.

North East Coast Institution of Engineers and Shipbuilders

NEWCASTLE-UPON-TYNE
"Some Practical Effects of Tip Clearance in Turbine Blading," by J. L. Jefferson. Neville Hall, Westgate-road, Newcastle-upon-Tyne. Fri., April 23, 6.15 p.m.

Royal Microscopical Society

LONDON
"A New Lamp for Visual Microscopy" and "A Re-designed Rousslet Compressor," by Dr. J. R. Baker (with demonstrations); and "A Simplified Micro-Manipulator," by Dr. R. J. Goldacre (with demonstration). Wed., April 21, 5.30 p.m.

Royal Statistical Society

NEWCASTLE-UPON-TYNE
Annual General Meeting, 6.45 p.m. "Sensory Tests in Industrial Research," by K. R. Williams, 7.15 p.m. Armstrong Buildings, King's College, Newcastle-upon-Tyne. North-Eastern Industrial Applications Group. Wed., April 21.

Sheffield Metallurgical Association

SHEFFIELD
"Powder Metallurgy as an Aid to Production," by G. R. Bell. B.I.S.R.A. Laboratories, Hoyle-street, Sheffield, 3. Tues., April 13, 7 p.m.

Sheffield Society of Engineers and Metallurgists

SHEFFIELD
Film Evening. Monday, April 19, 7.30 p.m.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

Association of Supervising Electrical Engineers, 54 Station-road, New Barnet, Hertfordshire. (BARnet 9141.)
British Institution of Radio Engineers, 9 Bedford-square, London, W.C.1. (MUSeum 1901.)
Chemical Society, Burlington House, Piccadilly, London, W.1. (REGent 0675.)
Illuminating Engineering Society, 32 Victoria-street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institute of British Foundrymen, St. John Street Chambers, Deansgate, Manchester, 3. (Blackfriars 6178.)
Institute of Fuel, 18 Devonshire-street, London, W.1. (LANgham 7124.)
Institute of Marine Engineers, 85 The Minories, London, E.C.3. (ROYal 8493.)
Institute of Petroleum, Manson House, 26 Portland-place, London, W.1. (LANgham 2250.)
Institute of Road Transport Engineers, 69 Victoria-street, London, S.W.1. (ABBey 6248.)
Institution of British Agricultural Engineers, 24 Portland-place, London, W.1. (LANgham 3394.)
Institution of Chemical Engineers, 56 Victoria-street, London, S.W.1. (VICtoria 6161.)
Institution of Civil Engineers, Great George-street, London, S.W.1. (WHItehall 4577.)
Institution of Electrical Engineers, Savoy-place, Victoria-embankment, London, W.C.2. (TEMple Bar 7676.)
Institution of Engineers-in-Charge, 100 Earlsfield-road, London, S.W.18. (BATtersea 1394.)
Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. (Central 5181.)
Institution of Locomotive Engineers, 28 Victoria-street, London, S.W.1. (ABBey 6672.)
Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Mining and Metallurgy, Salisbury House, Finsbury-circus, London, E.C.2. (MONarch 2096.)
Institution of Naval Architects, 10 Upper Belgrave-street, London, S.W.1. (SLOane 4622.)
Institution of Production Engineers, 36 Portman-square, London, W.1. (WELbeck 6813.)
Institution of the Rubber Industry, 12 Whitehall, London, S.W.1. (WHItehall 5012.)
Institution of Structural Engineers, 11 Upper Belgrave-street, London, S.W.1. (SLOane 7128.)
Junior Institution of Engineers, 39 Victoria-street, London, S.W.1. (ABBey 6968.)
Liverpool Engineering Society, 9 The Temple, 24 Dale-street, Liverpool, 2. (Central 3717.)
Newcomen Society, 43 King's-road, London, S.W.3. (SLOane 8883.)
North East Coast Institution of Engineers and Shipbuilders, Bolbec Hall, Newcastle-upon-Tyne, 1. (Newcastle 20289.)
Royal Microscopical Society, Tavistock House South, Tavistock-square, London, W.C.1. (EUSton 2048.)
Royal Statistical Society, 21 Bentinck-street, London, W.1. (WELbeck 7638.)
Sheffield Metallurgical Association, 15 Crescent-road, Sheffield, 7. (Sheffield 53674.)
Sheffield Society of Engineers and Metallurgists, University of Sheffield, St. George's-square, Sheffield. (Sheffield 24071.)